BEST PRACTICES IN USER NEEDS/REQUIREMENTS GENERATION

by

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B.S., Engineering Sciences (1994)

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Submitted to the System Design and Management Program
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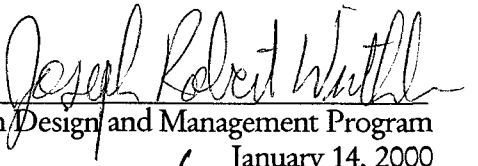

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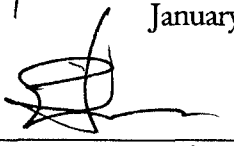

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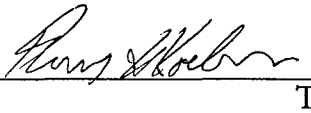

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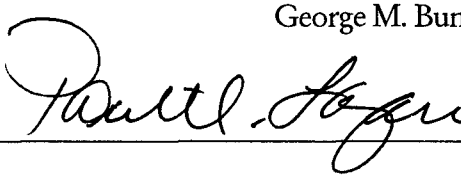

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BIOGRAPHICAL NOTE

Joseph Robert Wirthlin – born in Michigan, Robb grew up in the suburbs of Salt Lake City, UT. Graduating in 1988 from Skyline High School, Robb entered the US Air Force Academy with the Class of 1992. After a two-year proselyting mission for the Church of Jesus Christ of Latter-Day Saints to Dresden in the German Democratic Republic and also to Berlin in the Federal Republic of Germany, Robb graduated from the Air Force Academy in 1994. Earning a Bachelor of Science Degree in Engineering Sciences and a Minor in German, Robb was commissioned a Second Lieutenant in the US Air Force and married Robin Olsen in June of 1994. Robb's first assignment was to Hill AFB, UT. He served as Program Engineer on two aircrew training systems, the KC-10 and KC-135. Upon completion of that tour of duty, Robb was serving as the Chief Systems Engineer on the programs and learning all about fatherhood with his daughter, Riana. Pursuing a dream of higher education, the Air Force assigned Robb to the Massachusetts Institute of Technology in January 1998. Being the first Air Force Officer in the prestigious Systems Design and Management Program at MIT, Robb was able to apply his experience from his previous assignment to his coursework as well as the research he conducted for the Lean Aerospace Initiative. Among the highlights during this time was being able to serve as a Team Member of the Headquarters Air Force 2002 Requirements Reengineering effort. The arrival of his son, Joey, serves as the source of some of his fondest memories during this time. Upon completion of this degree and thesis, Robb will be pursuing Program Management opportunities at Los Angeles AFB, CA. He is a member of Sigma Gamma Tau (the Aerospace Engineering Honor Society), the American Institute of Aeronautics and Astronautics (AIAA), and INCOSE (International Council on Systems Engineering). Active in church and community service activities, Robb enjoys spending his free time with his family.

Hill AFB has recognized Robb for his outstanding efforts through various awards and recognition. He was named a Company Grade Officer of the Quarter for his division and was later the Hill AFB nominee for the Oberland Engineering Award. The US Air Force Academy has also nominated Robb for the Olmstead Scholarship Competition. His peers at MIT have also recognized him by election to various Student Councils and Leadership Forums.

Robb is looking forward to applying the material learned at MIT, particularly the information relating to New Product Development.

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ABSTRACT

A process framework for the front-end of product development was developed. The framework covers the process space from an initial need (or recognition of need) to the decision for a product/development program launch. The framework focuses on the activities required for the development of requirements needed for an investment decision. The framework was developed through a thorough examination of the literature relating to product development and addresses not only the activities required to traverse the front-end, but also metrics and a process maturity matrix by which an organization can be evaluated.

Using case studies of the front-end processes of eight commercial organizations and eight military organizations in addition to the US Air Force, the framework was tested. All of the organizations demonstrated the existence of the four fundamental activities contained in the framework but an examination of the existing process enablers revealed various interpretations of required features. The maturity matrix was used to evaluate each of the organizations (commercial and military) relative to the front-end process in the framework. The analysis revealed a significant gap between commercial and military process performance. The existence and application of the process enablers was significantly correlated with the organization's performance in the four process activities of the framework.

The implications of the research indicate that military organizations need to reevaluate their current practices in the front-end and the application of process enablers within their organizations. Further, military organizations should reexamine if the current process structure for system development in the front-end need significant changes.

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Most importantly, the author expresses his deep love and appreciation to Robin, wife and best friend, and his children, Riana and Joey, for their support and help through this long and sometimes trying process. They have been a source of inspiration as well as a great reality check – without which this experience would have been far less rewarding.

Glossary / List of Acronyms

ACAT	Acquisition Category
ACC	Air Combat Command
ACTD	Advanced Concept Technology Demonstration
ADM	Acquisition Decision Memorandum
AF	Air Force
AF/IL	Air Force Deputy Chief of Staff for Installations and Logistics
AF/SC	Air Force Deputy Chief of Staff for Communications and Information
AF/SG	Air Force Surgeon General
AF/SP	Air Force Deputy Chief of Staff for Security Police
AF/TE	Air Force Deputy Chief of Staff for Test and Evaluations
AF/XO	Air Force Deputy Chief of Staff for Air & Space Operations
AF/XOC	Air Force Director of Command and Control
AF/XOI	Air Force Director of Operational Intelligence
AF/XOR	Air Force Director of Operational Requirements
AF/XP	Air Force Deputy Chief of Staff for Plans & Programs
AF/XPP	Air Force Director for Programs
AF/XPX	Air Force Director for Strategic Planning
AFB	Air Force Board
AFC	Air Force Council
AFG	Air Force Group
AFI	Air Force Instruction
AFOTEC	Air Force Operational Test and Evaluation Center
AFPD	Air Force Policy Directive
AFROC	Air Force Requirements Oversight Council
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AMC	Air Mobility Command
AoA	Analysis of Alternatives
APB	Amended President's Budget
APOM	Amended Program Objective Memorandum
APPG	Annual Planning and Programming Guidance
AST (C3I)	Assistant Secretary of Defense for Command, Control, Communications and Intelligence (C3I)
BES	Budget Estimate Submission
BoD	Board of Directors
C4I	Command, Control, Communications, Computers, and Information
CAIV	Cost as an Independent Variable
CG	Chairman's Guidance
CINC	Commander-in-Chief
CJCS	Chairman of the Joint Chiefs of Staff
CONOPS	Concept of Operations
CPA	Chairman's Program Assessment
CRD	Capstone Requirements Document (usually for 2 or more ORDs)
CSAF	Chief of Staff of the Air Force

DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DCS	Deputy Chief of Staff
DoD	Department of Defense
DPG	Defense Planning Guidance
DRB	Defense Resources Board
FFRDC	Federally Funded R&D Center
FOSG	Flag Officer Steering Group
FY	Fiscal Year
FYDP	Future Years Defense Program
ICT	Integrated Concept Team
IOC	Initial Operational Capability
IPL	Integrated Priority List
IPT	Integrated Product Team
IRSS	Integrated Requirements Support System
J-8	Joint Directorate of Requirements and Planning
JCS	Joint Chiefs of Staff
JRB	Joint Review Board (pre-JROC)
JROC	Joint Requirements Oversight Council
JRP	Joint Review Panel
KPP	Key Performance Parameters
LRP	Long Range Plan
M&S	Models & Simulations
MAA	Mission Area Analysis
MAA	Mission Area Assessment
MAJCOM	Major Command
MAP	Mission Area Plan
MAT	Mission Area Team
MAWG	Mission Area Working Group
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Programs
MIP	Modernization Investment Plan
MNA	Mission Need Analysis
MNS	Mission Needs Statement
MOE	Measure of Effectiveness
MOP	Measure of Performance
MPP	Modernization Planning Process
MSA	Mission Solution Analysis
MSP	Mission Support Plans
MT	Mission Task
NMS	National Military Strategy
NSC	National Security Strategy
O- (number)	As in Officer Grade – (number) (e.g. O-6 is a Colonel, O-10 is a General)
OAS	Office of Aerospace Studies
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT&E	Operational Test & Evaluation

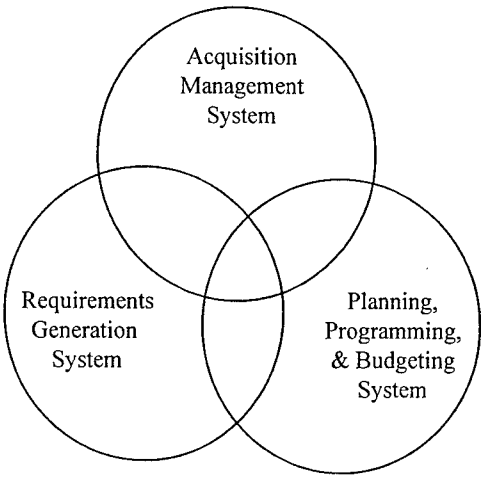
PB	President's Budget
PBD	Program Budget Decision
PDM	Program Decision Memorandum
PE	Program Element
PEM	Program Element Monitor
POM	Program Objective Memorandum
PPBS	Planning, Programming and Budgeting System
QFD	Quality Function Deployment (House of Quality)
R&D	Research and Development
RAD	Requirements and Acquisition Division
RAWG	Requirements Action Working Group
RCM	Requirements Correlation Matrix
RDT&E	Research, Development, Test & Evaluation
RGS	Requirements Generation Systems
SAF/AQ	Secretary of the Air Force for Acquisition
SAF/FM	Secretary of the Air Force for Finances (e.g. FMB for funding and FMC for cost issues)
SECAF	Secretary of the Air Force
SECDEF	Secretary of Defense
SON	Statement of Operational Need
SPO	System Program Office
SPRS	Space Planning and Requirements System
TOA	Total Obligation Authority
TPIPT	Technical Planning Integrated Product Team
USD (A&T)	Under Secretary of Defense for Acquisition and Technology (A&T)
USSOCOM	United States Special Operations Command

CHAPTER 1 - DEVELOPING THE NEEDS AND REQUIREMENTS FOR WEAPON SYSTEMS IN THE US AIR FORCE

Currently, the processes in place to acquire new systems for the military are very formal and take a long time to navigate. Current estimates of the time required to traverse the system are between 15 and 20 years (Stanley 1994);(See Gansler 1989). The time indicated is somewhat deceiving as it typically refers to the 'start' of a new acquisition program. The term 'start' usually refers to the point in time when resources have been allocated to finish the project. However, what about all of the activities that must come before the 'start'?

The commercial world has by practice refrained from entering into new development projects without understanding the ramifications of such an action. Most companies present the pros and cons of any new venture in some kind of formal document and use it to base their decision. This formal document is known as a 'business case'. It clearly states the 'case' for the 'business' of the new venture. Obviously, these business cases do not appear magically. They take time to develop and yet, not too much time that would give a competitor the upper hand. They must be done correctly too, as some companies 'bet the business' on new product decisions. In product development "the front end is inherently fuzzy because it is a crossroads where complex information processing, a broad range of tacit knowledge, conflicting organizational pressures including cross-functional inputs, considerable uncertainty, and high stakes must meet" (Khurana and Rosenthal 1998, pg.72). For the United States Military, the front-end consists of the initial processes leading towards the development of programs and systems.

The description of this pre-activity in the commercial world is known as the "fuzzy-front end" of product development. In the military, three separate processes participate in the "fuzzy front-end" of the development of a weapon system. These are known as the Programming, Planning, and Budgeting System (PPBS), the Requirements Generation System (RGS) and the Acquisition System. Each of the services designates particular portions of these processes by different names. The degree of formality and complexity among the services' portions also vary.



(CJCS 1999)

Figure 1. Weapon System Development Requires Intersection of Three Separate Systems

A three-pronged effort is required to begin a program; first, user 'validation and approval' of the need through the RGS, second, a place in the budget of the service for the program through the PPBS, and third, approval from the proper Acquisition authority. Portions of these systems are often happening in parallel and can be quite complicated. The PPBS requires at least two years to get money programmed and budgeted until resources are able to be expended on a project of any kind. The Milestone Decision Authority (MDA) from the Acquisition System must agree that both of these conditions have been met, and any other levied upon the program, before further product development may begin and a Milestone Decision is reached.

The current process, as explained above, for the front-end is difficult to quantify. However, assuming front-end processes are executed serially, and also that the recommended process cycle times occur, a relative cycle time for the process can be estimated. For example, strategic planning, which can take up to a year, feeds both the Requirements System and the PPBS. To review the notional cycle times, the PPBS requires 2 years, and the Requirements System requires 1/2 to 2 years to traverse. Therefore, a 'requirement' in the DoD takes approximately 2 1/2 to 4 years to result in a Milestone 0 decision. This amount is an addition to the commonly quoted weapon system cycle time of 15 to 20 years. Add another 2 1/2 to 3 years at least (because an AoA requires 6 to 18 months and the ORD

has to traverse the RGS as well) until a Milestone I decision is made and the program is formally started and turned over to the acquisition community. These numbers equate to a grand total of 5 to 7 years required to make an investment decision for the services on a weapon system acquisition.

Also, it appears that 'radical' or 'unprecedented' leaps of technology and performance require a much longer amount of time to emerge from the overall front-end system. For example, the F-22 Concept Development, from initial idea generation to program start, required nearly 11 years. The first foray of exploratory work began in the early 70s and did not enter the Acquisition Process until November 23, 1981 (Aronstein, Hirschberg et al. 1998). Part of the time delay can be explained by the timing of the concept development. During the time of the F-22 Concept Development, the Air Force was conducting several major aircraft purchases, including the F-15 and the F-16 aircraft. Additionally, the B-1 and B-2 bombers were acquired during the 1980s and the C-17 during the 1990s, diverting vast amounts of procurement dollars to these systems.

The Problems

Despite the appearance that the military's front end is systematic in the course of developing systems, it exhibits many characteristics that make its processes appear ad hoc. There is no standardized approach to the front-end of product development in the military, especially in developing the concept through actually developing the requirements for the system (Laubengayer and Spearman 1994). What is wrong with ad hoc processes? The results can be less than desirable or completely wrong.

The public has heard it all before - the legendary $600 hammers, the $1,000 Allen wrenches, $5,000 coffeepots, wasted resources, and so on (Gregory 1989). The warfighter feels shortchanged as well and reacts poorly to these discoveries. They view all those who participated in the process, most notably the defense contractors and acquisition personnel, with a lack of confidence, distrust and suspicion. This atmosphere does not bode well for any program. Additionally, the current process to develop weapon systems is being blamed for several shortcomings in the military. One notable shortcoming is that the current system is unresponsive to a rapidly changing threat environment. A recent example of this shortcoming was highlighted when the process failed to recognize in time (or at all) the threat of changing radar waveform patterns. Radar waveform patterns stored in aircraft defensive systems must be constantly updated to reflect the latest changes used by anti-aircraft

weaponry. The lives of pilots patrolling the Iraqi No-Fly Zone were jeopardized and it left the US military scrambling for a solution (Fulghum 1998).

What is wrong with a poorly articulated requirement? An example of this is when the Army mandated using their existing vehicles and refused investing in another type of vehicle for a truck mounted anti-missile battery. This single requirement 'drove the solution' to a system that could only hold two missiles, although the acceptable range of accuracy required could only be achieved with a minimum of four missiles (DOD 1998). In essence, it was a total failure of the system to produce and field a weapon system that met user needs. "The user in the above scenario had a legitimate concern; however, stating that simple and logical logistical requirement {to use existing vehicles} drove the process to an expensive design solution. Consideration of possible alternatives - remotely piloted vehicles, airborne lasers, satellites, high energy weapons, kinetic kill weapons - was eliminated" (DOD 1998, pg. 51) almost from the start.

The cost to realize requirements in a materiel solution has received the most attention in the formal literature. Consider this quote. "The United States has clearly kept its military equipment at the technological forefront, but the cost of this has been an increase of around 5 -7 percent per year in the unit cost of each new generation of equipment (even after adjustment for inflation and for the higher unit prices associated with the reduced quantities typically purchased today). ... Therefore, it is not surprising that, as costs have been rising, we have been buying fewer and fewer weapon systems. For example, in 1955 the Department of Defense spent approximately $7 billion (adjusted to 1982 dollars) to procure approximately 1,400 military aircraft. By 1982 it was spending $14 billion a year for approximately 200 aircraft. This trend continues to hold true with the production of the new F-22. Low-volume production runs further strain the relationships between requirements, acquisition, and the budget. Furthermore, additional problems result from the differences between the systems initial estimated costs and the final price tag" (Gansler 1989, pg. 7). Assuming that current development costs of new weapon systems for the US Air Force will continue to increase at historical rates, resources will soon be outstripped by demand unless something is done. Augustine observes that given current trends, the unit cost of one tactical aircraft will currently outstrip the entire defense budget by 2054 and the entire gross national product by the mid 2100s (Augustine 1983).

According to one study, the cost of defining requirements poorly is high. Given a $200 billion dollar acquisition budget (in 1987 dollars), the direct cost of poorly defined user needs and requirements ranges between $16 to $24 Billion dollars – 8% to 12% of the budget (Schlesinger 1987).

Table 1. Potential Cost Savings from Better Requirements

Cost Category of Cost Savings	Budget Impacted	Level Impacted	Ranges of Realistic Improvement	Near	Mid-Long	Total
Requirements, Excesses	$100	20-40%	10-15%	1	14	10-15
Over Specification, Errors	$150	5-15%	4-6%	2	7	6-9
Totals	$200	24-61%	12-25%	$3	$21	$16-24

(Schlesinger 1987).

Gansler, whose unpublished paper was used to determine some of the numbers in Table 1, published a more detailed explanation of these numbers. Those of greatest interest are found in an excerpt from his book. In this example, Gansler indicates that approximately $23 Billion is 'realistic' from a $300 Billion Defense Budget (i.e. he acknowledges that there will be no "perfect" system with no inefficiencies) in the amount of savings with improved requirements definition. This amounts to about 7.5% of the defense budget each year.

Table 2. Problem Areas with Potential Annual Savings

Problem Area	Rationale for Efficiency	Potential annual savings from a $300 Billion Defense Budget (in billions of 1989 dollars)
Designs primarily for maximum performance (with "gold plating")	"Design to Cost" and producibility should save a net of 10% of production costs	$15
Excessive Specifications (product and process)	Over-specification raises acquisition costs by 5%	$8

Source: (Gansler 1989, pgs. 341-342)

The potential savings in this area are staggering, and these are simply reflections of his 'realistic' assessment. This does not imply what a 'perfect' system could save overall. He does estimate that

when pursuing the last 5% of performance requirements in a system the total cost of the program may increase by as much as 30 percent (Gansler 1989).

A recent survey of government and contractor program managers (post Milestone I) indicated that problems caused by or stemming from Requirements cause program cost growth at a rate of 2.7% annually. Schedule slips of 11.9% from program start to IOC are not uncommon (Rebentisch 1996). This figure seems in line with the percentage indicated by Gansler. The somewhat lower percentage cited may be attributable to the changes brought about by Acquisition Reform in the US Air Force. However, to date, there have been no changes to the front-end process (pre-Milestone I) of the US Air Force. This information merely reflects the experiences of already existing programs (i.e. Requirements Management).

The cost to execute the overall process has rarely, if ever, been quantified. However, a case defining the process cost for one program run by the US Air Force was determined to be roughly 5% of the total program cost[1]. The process cost for development and generating requirements is clearly also something to consider.

What is the cause of these problems? While simply speculation, the answer to this question could be that the DoD commits too early to specific system characteristics and the intent of the customer is lost. Possibly, the customer or end user may simply not be able to communicate or articulate the need or operational requirement. Perhaps the developer or even the customer turn their focus on the technology rather than on addressing the fundamental requirements that the system needs to satisfy (Laubengayer and Spearman 1994). Here are some additional explanations why the current process leads to results that are less than desirable:

- There is an inefficient conversion of needs into detailed requirements. Vaguely defined operational requirements are often the result. Furthermore, these operational requirements don't flow efficiently as inputs to system requirements and the detailed technical requirements definition process downstream.

[1] The author participated in developing a case study that examined the process costs as part of a class project. The author was part of a team that presented this information as part of its final class project (Cocuzzo, Gruszka et al. 1999). This project is available upon request.

- There is a long needs-generation process with multiple steps, and it seems to be accomplished using a serial process. Numerous organizations participate in the review of Requirements documents. The hierarchical nature of the military means that requirements must "go up" the chain of command before being seen by the ultimate decision-makers. Releasing a document "to the outside" from within an organization requires high-level sign-off. (This is both between MAJCOMs[2] as well as between the different services.) Revisions may require numerous iterations through the chain of command.

- Because of the currently long product development time, large steps in performance are required to justify the need for a new system vs. incremental upgrades. That gives more opportunity for requirements changes as technology and threats evolve.

- The DoD joint planning process acts more as a filter than a coordination process (e.g., the individual services are free to start programs that may duplicate an existing capability in another service.)

- Requirements are stated that aren't absolutely necessary to complete the mission, by either the operational users (or customers), and/or those that are responsible for acquiring these systems. The reasons for this vary, but probably range from a lack of trust between the different disciplines to stating requirements because 'they had always done so.'

- There is a failure to explore all possible alternative solutions, as in the previously mentioned example from the Army. There is a perceived need to 'hurry up' results for a rapid convergence towards a single solution without full analysis. Existing solutions (e.g., off the shelf, contractor proposed, etc.) are envisioned as the preferred option before consideration of actual mission needs or possible alternatives, which is actually contrary to existing policy. For example, existing US Air Force policy dictates the first and most important step is to understand the mission need and then search for potential solutions (USAF 1996; USAF/DXOR 1999).

[2] A MAJCOM is a Major Command in the United States Air Force. There are similar terms used for equivalent organizations in the other US military services. A commercial analogy is that of a Company Business Unit.

- There are unrealistic mission statements. There is also a lack of measures or analysis identifying relative cost effectiveness of varying levels of capability. Mission requirements maybe "cut and pasted" from previous requirements documents without sufficient review. Missions or threats may be unrealistic or no longer exist in current form in the time required to develop and field the capability.

- Combinations of requirements exist that taken in concert are costly to realize. There is a lack of awareness or consideration of how specific mission requirements may conflict with various other elements of the system.

- Different organizations are responsible for different aspects of the system, with little communication and/or budgetary coordination. Only enough funding is provided (in some cases) to complete analysis and/or development of requirements for a single element of a larger system or system of systems. A Joint program has many "Requirers" but only one or a few organizations are responsible for the funding and execution of the program.

This list does not imply that the source of all of these shortcomings are known or easily solved. Rather, it builds a case that the current process is not responding to the needs of the warfighter.

The military is full of examples of trying to deal with the earlier mentioned problems of the front-end. One such method is the Air Force's Rapid Response Process (RRP), used recently during the conflict in Kosovo. The process is "designed to streamline the acquisition process by reducing the layers of bureaucracy, thereby delivering a capability more rapidly. The RRP objective was to submit, assess, approve, and fund a validated Combat Mission Need Statement (C-MNS) within 24 days and implement procedures to field the desired capability in less than six months" (Smith 1999 pg. 28; See also USAF/DXOR 1999). The drawback to this process is that it is only used during conflicts (military action of prolonged duration). However, based on the results of its use during Desert Shield/Desert Storm (24 out of 30 projects were approved and were delivered to the field within five months; costs of acquisition and production were under $100 Million), this process seemed to work well (Smith 1999). There are other processes used by the Air force as well. One is the Short Method to Acquire Ready or Replacement Technologies (SMART). This method is for "mature solutions... that are fully funded and have the potential to be acquired and fielded quickly"

(USAF/DXOR 1999). Reasons for using these alternative methods to the existing process are varied, but are usually the result of trying to shorten the typical acquisition cycle. Examples of how to do this include the use of Advanced Concept Technology Demonstrators (ACTDs)[3], Advanced Technology Demonstrators (ATDs), Commercial and Non-Developmental Items (CaNDI), Joint Warrior Interoperability Demonstrations (JWID) Gold Nuggets, Kenney Battlelab initiatives, Expeditionary Force Exercise (EFX)-type initiatives and others (USAF/DXOR 1999). But these methods, which are developments of the 1990s, are responses to some of the visible symptoms of the current system. They do not contribute to understanding the root causes or solving them. Rather, they seek to shorten development time by either taking shortcuts through existing processes or circumventing them altogether. The RRP and SMART processes only make these shortcuts and circumvention acceptable and permissible.

Qualitatively, problems exists in the way the military - and more specifically, the US Air Force, generates requirements. How can this problem be really quantified? One way to determine this is to compare the front-end process of the Air Force against the other military services and also industry. What will distinguish superior processes from all others? For the purposes of this study, a truly systemic or 'holistic' approach to the front-end is hypothesized to be better than an ad-hoc one. One might argue that the requirements system of the US Air Force is very methodical, even systematic. This is true. But does the Air Force have a system that is really 'holistic' in its approach to new product development or does it promote processes and practices that contribute to the previously listed shortcomings? The USAF and the other services will be evaluated to answer this question.

The Packard Commission made the following assertion about the overall process: "The more time, care, and money invested at the front end of a project, the quicker and cheaper a better and more reliable end product will get into the hands of the forces" (Gregory 1989, Pg. 19). There have been many studies and proposals made on how to improve the current front-end process of the military. Appendix G contains detailed information about many of these studies and proposed changes to the front-end process, particularly the planning stages. FFRDCs or non-profit agencies such as RAND have generated most of these proposals. Most of these were also done at the request of the US Air

[3] The reader is referred to DoD literature for more background on these issues (USAF/DXOR 1999).

Force and are specific to the Air Force front-end process. Table 7 summarizes the information contained in Appendix G.

Table 3. Proposed improvements to the current Air Force System

Concept	Source of information	Process affected	Overview
Reorganize OSD (A&T)	Bracken	All	Create Science & Technology office; Concept Development & Integration Office; and Acquisition Office
Crisis-Action Planning	Davis	PPBS, MPP	Use exercises; stress flexibility and adaptiveness
Assumption Based Planning	Dewar	PPBS, MPP	Thinking about uncertainty and organizational issues
Constraining the MPP	Farr	MPP, PPBS	Use an IP model to determine correct mix of resources for systems
Modernization Investment Plan	O'Riorden	MPP, PPBS	It is a goal-programming tool that links strategy with available resources.
Concept Development Framework	Lewis	MPP, Requirements Generation System	Supports the formation of Concept Operations Groups to refine conceptual ideas
Operational Acquisition	Smith	Requirements Process, Acquisition System	Further integration of operational warfighter (CINCs) into development and acquisition of systems

None of these studies or reports has looked at the overall product development system of the military. This work will examine the entire system from a holistic viewpoint in order to provide additional recommendations, based on sound reasoning and supporting evidence, on ways to eliminate the current problems in today's process.

Scope of the investigation

The Air Force and the DoD typically deal with products that are technologically advanced, very capital intensive, and very complex, both from an architectural and platform perspective. Other industries

with similar circumstances include commercial aerospace and commercial airliners. Additional industries worth examining are those with rapidly evolving technology and highly complex development and manufacturing processes.

The goal of this research is to be explanative in nature and to answer real world questions. The leading theories in this area have not looked primarily at highly complex, technologically advanced, capital-intensive products. This study seeks to extend the application of these theories into this area and identify the best practices in use. This effort will look at the fuzzy-front end in view of these conditions in these industries and also compare them. The desire of this research is to be both broad and deep across the spectrum of applicability.

'Best practices' among the different industries will be highlighted and clarified. Potential applications will be demonstrated through the products contained in this work, as they apply to both commercial and military settings. This research will also serve to benchmark the existing practices of these industries and also document any trends that exist versus what existing theory prognosticates. Finally, a tool will be developed to enable any organization, commercial or military, to determine visually where they are compared to other organizations and best practice.

The ultimate objective of this research will be to develop policy recommendations that encourage implementation of best practices into the "fuzzy front-end" of weapon system product development for the US Air Force. The following dialogue in this work will demonstrate the potential for improvement in the fuzzy front-end of weapon system development in the US Air Force. Indeed, there is much to be gained by looking at the military at large and doing so in comparison with the best the commercial world has to offer.

Hypothesis/Assertion

The core assertion of this research is that a systematic, holistic Requirements Process is better than an ad hoc one. "Flying by the seat of your pants" may work some of the time, but a planned process will consistently produce better solutions. Furthermore, the main hypothesis of this work is that without the proper application of organizational and business enablers, product development will not be as successful (as measured by outcome metrics) despite the existence of 'Best Practices' applied throughout the process.

As the framework asserts that Organizational and Business Enablers are required for an advanced front-end, and that an advanced front-end demonstrates characteristics that are desirable; it is hypothesized that the enablers will be positively correlated with each stage of the framework as well as with the overall process.

Key Questions

There are several questions that will be investigated during this research. Key questions being addressed by this research are:

1. What are the metrics and the current effectiveness of the Requirements Process in the US Air Force?

2. How does the AF process compare with other services? The commercial world? How do the processes compare with the results found in the literature?

3. What are the key elements of a process that uses Best Practices? How might identified Best Practices be applied to the US Air Force process? What is required to implement these Best Practices? Are there things inherent in the system that prevents widespread application of Best Practices?

Primary Deliverables

There are three primary products of this research.

1. A Front-end Framework (developed and presented in Chapter Three) categorizes and facilitates understanding of the current needs/requirements generation process in the Air Force, the other services, and representative commercial firms.

2. A Process Maturity Matrix forms the basic set of Best Practices for the Fuzzy Front End, derived from the framework and the other data sources.

3. Implications of and recommendations for policy changes in the US Air Force.

What this effort will not do

This effort will not look specifically at the Planning, Programming, Budgeting System, the Requirements Generation System, or the Acquisition System. However, the intersection/interfaces of these three and other processes will be discussed and evaluated as part of this research. Any evaluation of the military's front end will be done from an integrative viewpoint, or holistic viewpoint, rather than parsing functions or activities into separate systems. There is currently other research underway by the Institute of National Security Studies, the Pentagon[4] and the General Accounting Office evaluating the strengths and weaknesses of these systems separately. Opportunities for synergy with the above named efforts will be aggressively pursued.

Furthermore, Requirements management - an activity defined to occur after the initial set of requirements has been determined - will not be examined. This is beyond the scope of this effort.

Summary

In general, the issues dealing with the front-end of product development are being fiscally constrained, having effective measurement, avoiding stovepiping activities, maintaining the correct focus, strategy, and accountability, all while doing it in a timely manner. These issues are important to the US Air Force, the entire DoD and to the entire US Government. Indeed, these issues can be extended to commercial companies because they have widespread application.

The current process used by the US Military to take user needs and requirements and develop them into a set of coherent ideas, (along with maturing the idea and establishing the organizational momentum to get a project started), is complicated at best and very difficult to navigate. Furthermore, adding the actions of strategy and planning, along with the budgeting process for obtaining the necessary funds to develop these requirements into a fielded capability, although not necessarily timely, to a holistic view of requirements generation turn that view into one of disappointment and extreme concern. The system probably functions only as well as it does thanks to the dedication and sacrifice of those people working within the system.

[4] A Section 912 Requirements study looking at the Requirements Process and its interface with the other processes.

The key issues to be addressed in this work are those revolving around the 'process' of the fuzzy front-end. These include measures such as cycle time, enablers such as common communication platforms, and interfaces between the various parallel processes that need to be coordinated (or overall system process design). How does the current system (in the US Military generally and the US Air Force specifically) really work? Where are its strengths and weaknesses? What can be learned by looking at various industries and the processes they use at the front-end of their product development processes? Answering these questions will likely reveal a set of best practices for user needs/requirements generation.

This work aims to provide the decision-maker with an idealized front-end process and accompanying measures so that existing processes and procedures may be evaluated. Furthermore, a maturity matrix will be presented to show process maturity and room for improvement along with implementation suggestions to move toward best practices in user needs and requirements generation within the 'fuzzy-front-end' of product development.

CHAPTER 2 - SETTING THE STAGE FOR UNDERSTANDING THE PROBLEMS

This chapter will examine some of the latest thinking about the 'fuzzy front-end' of New Product Development in commercial industry. Its strengths and weaknesses will be discussed. Next, the military process will be discussed relative to the existing literature. Finally, the drawbacks in the literature will be discussed. This sets the stage for the development of the research.

Lean Thinking and Lean Principles for the front-end

During the early 1980s, the U.S. Industry, and the U.S. Automobile Industry in particular, was suffering from a flood of foreign goods to the consumer market that were of higher quality and sold at much lower prices. The U.S. Defense Industry mirrored those problems of high-cost although quality was still good enough on US Military products for them to be sold to our allies and other nations. However, the U.S. Defense Industry had one advantage over their other industrial counterparts – the Defense Industry's customer, the U.S., was forced to buy from them the systems that were produced (Gansler 1989).

The crisis in industry kicked off an effort at MIT that later resulted in the publishing of "The Machine That Changed the World." It specifically addressed the challenges the American automotive industry faced along with addressing how another country's industry was doing so well. Out of this understanding grew the concept, principles, and paradigm of "Lean". Thinking in a lean fashion requires one to address five specific areas: value defined in terms of the product; the 'value stream' for each product; allowing value to 'flow' without interruptions; forcing the customer to 'pull' value from the system; and pursuing perfection (Womack and Jones 1996). Furthermore, value is directly opposed to 'muda', Japanese for waste. Muda is any activity that absorbs resources but adds no value or creates no value (Womack and Jones 1996). The challenge remains to be seen if the American aerospace industry, particularly those involved in defense, can apply the principles of lean.

The Lean Aerospace Initiative has done much to develop the knowledge and diffuse it through the aerospace industry in the 1990s. In this regard, product development has become an area where little

information has existed relative to the principles of "lean". Part of the reasons for this is that muda has always been defined in terms of manufacturing or physical operations. Muda has several known forms: "defects (in products), overproduction of goods not needed, inventories of goods awaiting further processing or consumption, unnecessary processing, unnecessary movement (of people), unnecessary transport (of goods), and waiting (by employees for process equipment to finish its work or on an upstream activity)" (Womack and Jones 1996, pg. 313). Womack and Jones added "the design of goods and services which do not meet users' needs" (Womack and Jones 1996, pg. 313). These forms of waste have equally analogous forms within product development (Womack and Jones 1996).

Most commercial industries have become revitalized over the past decade as Lean Principles and Lean Thinking have become an important part of everyday business and muda has been aggressively reduced and/or eliminated. The US is enjoying an era of unprecedented economic expansion and growth, yet the defense aerospace industry continues to struggle. Why is this so?

Part of the answer is that the defense department has remained relatively unchanged throughout the past quarter century, although calls for change and reform have become even more audible. Acquisition Reform in the US Air Force began in earnest in the mid-1990s. Drastic changes have since taken place and many improvements have resulted. However, the process by which the defense department generates requirements and plans for them, including resource allocation, have not changed at all. Therefore, the resulting tensions between systems undergoing tremendous changes and those that have not are reaching a clamorous level. Furthermore, until the military changes the way it goes about its product development business, the defense aerospace industry has little incentive to change and embrace the thinking and principles that have turned the rest of American industry around.

Commercial Industry has spent a lot of time and effort in focusing and improving their product development front-end in addition to just improving manufacturing processes and capability. A closer look at their experience in this area is warranted.

The Fuzzy front-end in the commercial world

This stage of new product development is a huge area of interest. The reasons for this interest are quite compelling in that the research has revealed information in what had been largely 'fuzzy' - information about practices, methods, and processes that has yielded success in new product development.

What is the importance of this information? Done well, the early phases of product development are associated with shorter development cycles, which facilitate the incorporation of newer technologies and improvements to products in production (Bacon, Beckman et al. 1994). Also, "recent research on product design and development processes suggests that the management and organization of the early stages of the process affect product success or failure in the marketplace" (Bacon, Beckman et al. 1994, pg.32).

Khurana and Rosenthal looked at an integrated approach to product development. Two important themes emerged from their research: the power that comes from a 'holistic' front end, and the importance of the organizational and business context in creating an effective front-end process (Khurana and Rosenthal 1998). An important prerequisite for creating a holistic front end is establishing links between business strategy, product strategy, and key decisions in the front end (Khurana and Rosenthal 1998).

"The early stages of new product development cycles are characterized by relatively low rates of expenditure and, accordingly, changes in product features or target markets incur lower cost penalties. Moreover, these early-stage decisions have significant implications for the costly "downstream" investments in the development, manufacturing, and marketing activities associated with a new product" (Bacon, Beckman et al. 1994, pg. 32). Research by Cooper and Kleinschmidt indicate from their study of 125 new product development projects in 8 different industries, successful projects spent twice the amount of money and almost twice the amount of man-days in the front end than did projects that failed (Cooper and Kleinschmidt 1988).

The fundamental purpose of these early stages, with their limited resources, is to gather the right kind of information in a way that allows the translation of user needs into requirements. Research by Gause and Weinberg indicate that a requirement changed in the design phase is 3 to 6 times more

expensive than changes in the initial requirements phase. Changing requirements during acceptance testing increases the cost of changing the requirement by 30 to 70 times verses changing it during the initial requirements phase (Cooper, Wooten et al. 1998).

Robert G. Cooper is probably the most notable researcher in this area. His work has been cited hundreds of times by other researchers in the field of new product development, especially that relating to the 'fuzzy' front end. Some of his more recent research echoes many of the same things written above. Cooper found that "having a high quality new product process had the strongest impact on business's new product performance" (Cooper 1996, pg. 465). A high quality process, according to Cooper, is one that contains: solid up-front homework; Sharp, early product definition; Strong market orientation (voice of the customer); Tough go/kill decision points; Quality of execution throughout; a complete, thorough New Product process; and a flexible process (Cooper 1996).

In his study of 203 industrial products, solid-up front homework (market and technical assessments), gave a new product a 43.2% better chance of success (Cooper 1996). From 103 Chemical products studied, those done with good homework had 2.4 times the success rate and 2.2 times the market share verses those done poorly (Cooper 1996). Similarly, "sharp, early product definition enhanced project success rates by 59.2 percentage points; such well-defined projects had 3.7 times the success rate and 1.6 times the market share as those which lacked definition; and product definition was significantly and strongly correlated with performance" (Cooper 1996, pg. 470). Finally, the customer or user plays an extremely strong role in successful new product development; 75% of all successful ideas come from them (Cooper 1996). According to the earlier SAPPHO[5] studies, "an understanding of user's needs was the most important discriminator between product success and failure ... and separated successes from failures in 83% of the cases" (Cooper 1988).

Khurana observed, "The primary front-end deliverables should be the product concept (clear and aligned with customers needs), the product definition (explicit and stable), and the project plan (priorities, resource plans, and project schedules)" (Khurana and Rosenthal 1997, pg. 106).

Rosenthal and Khurana propose several ways to enhance the effectiveness of product development efforts. They underscore the need for a project leader, a core development team, and an executive

[5] A study conducted by Sussex University, England (Rothwell 1985).

review committee, and emphasize that their roles must be complementary (Khurana and Rosenthal 1997). Once the roles for these people are explicitly defined, they suggest the following heuristics will make the front end less "fuzzy":

- "The core team resolves product definition and project planning issues or refers them to an executive committee.
- Responsibility for ensuring that product definition and concept testing are balanced between thoroughness and speed. This responsibility is given to one of the roles.
- One of the roles will ensure that resources are allocated to a project, as specified in the project plan.
- One of the roles will identify emerging technologies for inclusion in future product platforms.
- One of the roles will have the authority to ensure that products developed by several business units or a unit and one or more "partners" are aligned along product/component interfaces, development schedules, market focus, and technology commitments" (Khurana and Rosenthal 1997).

Additionally, they found prior to a funding decision, a team must make six key decisions. 1. Identify customer needs, market segments, and competitive situations. 2. Perform a technology evaluation of current capabilities and requirements, as well as the alignment with existing business and technology plans. 3. Identify core product requirements. 4. Test the concept. 5. Specify the resources needed to complete the project. 6. Identify key risks and challenges (Khurana and Rosenthal 1998). These are all typical ingredients of a business case prepared for a management decision.

The most fuzzy and least explicit of all pre-phase zero (pre-business case decision) activities are the visions about the business, the project, and the product (Khurana and Rosenthal 1998). These ideas must be clearly articulated for project success. The development of a business case for a new product helps in this articulation.

Murphy and Kidmar reiterate the need for a solid business case because it can be critical in evaluating a proposed project (Murphy and Kumar 1996). Additionally, they recommend a thorough evaluation and study of a proposed project prior to any development. This study should be a key component in the business plan. Also, "a feasibility study that assesses a project in terms of its compatibility with organizational strengths was found to be crucial for developing new products on time and within budget" (Murphy and Kumar 1996, pg. 439).

Natural barriers to achieving a holistic front end occur when communication requirements and coordination in the new product development process is not met. Why? First, "the sources of expertise are spread across organizational boundaries. This makes the problem 'sticky'[6] because the required information, expertise, and authority are likely to be located in different individuals or roles. The front end requires extensive information gathering and analysis to facilitate the development, testing, and refinements of the new product concept, but this information is not available in one place, role, or function. Second, key decisions to be made on technology, cost, schedule, risk, and organizational resources are highly interrelated. Lacking a holistic process, the authority for making these decisions is dispersed throughout the organization. Thus, these cross-functional decisions require an extraordinary degree of coordination among senior management, project managers, functional managers, and core team members. These linkages are difficult to achieve for normal design and development activities, but are even more so for the front end. Finally, since these sets of assessments transcend any single new product concept, the coordination requirements in the front end become very subtle. These include routine linkages among the already complex activities of strategy formulation, technology mapping, market analysis, portfolio analysis, and resource planning" (Khurana and Rosenthal 1998, pg. 67).

Khurana and Rosenthal propose three key components are required to enable achievement of the linkages discussed above. Additionally, these will bring more order and predictability to the front end: 1) A process orientation; 2) Explicitness of the product definition; and 3) A broader set of business considerations while making project justification decisions (e.g., understanding the business unit's product portfolio, and including supply chain considerations during product definition) (Khurana and Rosenthal 1998).[7]

Finally, Rosenthal and Khurana put together a table of the common success factors in the front-end of product development based upon earlier research and a literature review. There are four main areas of focus they identified.

[6] Idea first expounded upon by von Hippel (vonHippel 1988).

[7] For more information, please see table entitled "Where best practice is headed" in this article (Khurana and Rosenthal 1998).

Table 4. Common Success Factors in the Front-end of Product Development

Product Strategy	Product Definition	Project Definition	Organizational Roles
Product Strategy formulation and articulation Product Portfolio planning	Product Concept Clarity Customer Needs Product Definition Value Chain Considerations in Product Definition	Front-end Project Definition and Planning Resource Planning	Organizational Structure (teams, project manager) Leadership by Executive Reviews

(Khurana and Rosenthal 1998)[8]

Other ways to frame the front-end of product development

Numerous other authors have indicated ways to approach the issues surrounding the front-end of product development. Each of these is different in terms of the areas of focus as well as their applicability to the overall front-end of product development (some are very specialized and deal with specific occurrences). The various ways include techniques (such as the Missed Elevator Approach), measures (such as cycle-time measurements), theories (such as the theoretical framework of requirements generation), and analogies (such as the information assembly line). Appendix A describes in detail the frameworks that are presented in this table. The information presented in the appendix and table is not all-inclusive. There are virtually innumerable ways to address these issues. The appendix and table only give a sampling of the different kinds of methods available to frame the front-end of product development. The table highlights the key features as well as some of the perceived drawbacks of each framework by this author.

Table 5. Specific Frameworks to understand the Front-end

Suggested Practice	Proposed by	Key Features	Drawbacks
Front-end Process Capability Mapping	Khurana and Rosenthal (Khurana and Rosenthal 1998)	Classification scheme provides a measure of process maturity and can identify areas for improvement.	Method does not indicate what constitutes an 'area for improvement'; also relies upon detailed understanding of

[8] A table of common problems associated with a poor job done at the front end of product development is contained in (Khurana and Rosenthal 1998).

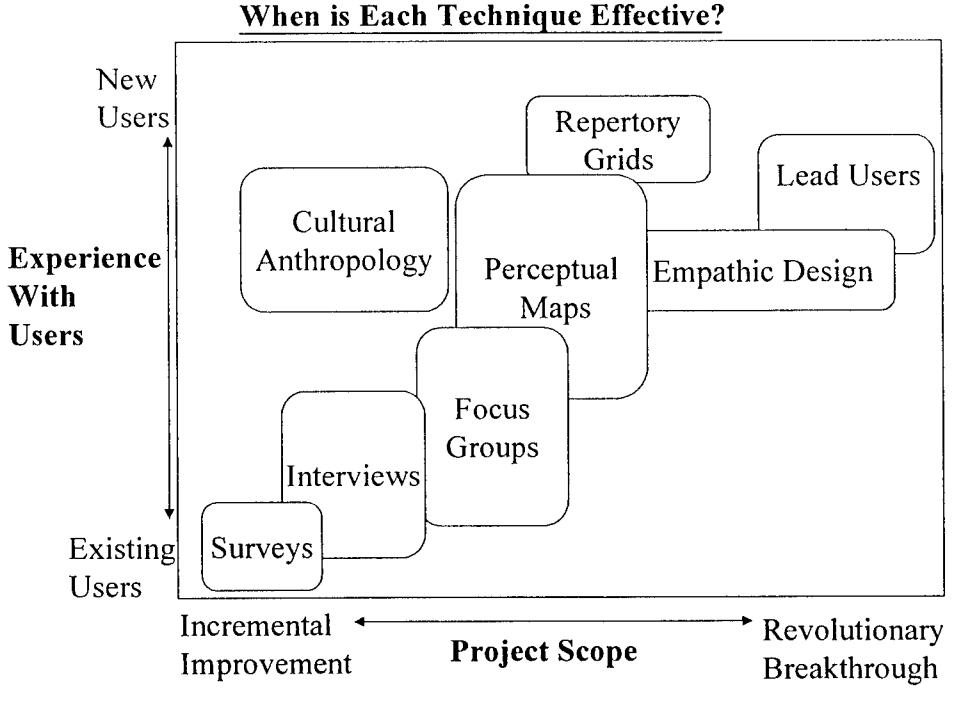
			existing process for application.
Missed Elevator	Khurana and Rosenthal (Khurana and Rosenthal 1998)	Freeze Requirements Early, put into next release	Relies upon short product cycles to be effective
Nyquist Theorem / Clockspeed	Patterson (Patterson 1993), Fine (Fine 1999)	Sample environment for requirements twice as often as process/system cycle time	Assumes cycle time is known and measurable.
Information Assembly Line	Patterson (Patterson 1993)	Applies techniques for assembly line management, operations management to knowledge	Assumes process in place supports these techniques. System must be correctly modeled in order for principles to be applied.
Organizational Competencies	Rosenthal (Rosenthal 1998)	Advocates organizational structures and approaches to development of new products	Most familiar to users. Requires dedication to principles and understanding of proper application.
Cycle Time in the Front – End	Patterson (Patterson 1993)	Statement of link between elapsed time and time to product launch decision	Metric is very difficult to measure as starting point is very ambiguous
Stages for Searching for User Needs / Requirements	Conway, McGuinness (Conway and McGuinness 1986)	Describes activities in development of requirements in organizational terms	Difficult to determine when one stage ends and the other begins.
Theoretical Framework to generate Requirements from Information	Cooper, Wootton (Cooper, Wooten et al. 1998)	Provides holistic framework of requirements development from organizational and individual perspectives.	It is difficult to identify internal and external sources of influence. It is also difficult to ensure that others are in complete understanding / agreement throughout the process.

Techniques to gather and evaluate user needs and requirements

In addition to using the frameworks above to understand the front-end process, several techniques exist that act to enable the front-end. Using one of these techniques is necessary for the proper

functioning of a product development front-end. These techniques are methods or ways to elucidate (such as using the QFD Process), gather (such as using Interviews and Surveys), and evaluate (such as the Pugh Method) user needs and/or requirements for the front-end. The process of the front-end deals with how these techniques are incorporated into the overall process that occurs. Appendix B contains a more lengthy discussion about some of the different techniques. The appendix is not all-inclusive; it serves to indicate the variety of methods available for the practioner to use.

When is each technique effective? According to Dahan, for an incremental product, surveys and focus groups could be used to identify the key needs, a conjoint analysis to prioritize the needs, and use QFD for concept selection. However, for a more revolutionary product, "leading edge users and repertory grids might help identify key needs, generate multiple prototypes, and conduct pre-market tests to observe actual customer usage" (Dahan 1998, pg. 2).



(Dahan 1998)

Figure 2. Notional Scope of Technique Effectivity

However, one of the dangers of listening too closely to customers comes from the example of the computer disk drive industry. Christensen of the *Innovator's Dilemma* has pointed out how previous industry players were listening to their customers so well that they failed to comprehend the new markets of customers emerging with new applications for computer disk drives (Christensen 1997). This is an example of 'disruptive technologies' that can change the dynamics of a given market (Bower and Christensen 1994). Ultimately, these industry players were shut out of the new markets. This highlights the delicate balance that must exist between listening to the user and interpreting what the user's true needs are.

Leonard-Barton, Wilson, and Doyle indicate three items developers must consider so that users' suggestions do not limit product designs. "First, they see the potential to apply technology within their own bounded context and will naturally influence the design of the new product or process to meet needs within that particular environment. ... Second, users are not all equally proximate to the latest trends in usage patterns. ... Finally, and most difficult, users cannot see their world through the eyes of the technologist and therefore cannot know what solutions, functions, enhanced features, or capabilities a technology may offer" (Leonard-Barton, Wilson et al. 1994, pg. 8).

Therefore, it is not only necessary to sometimes ignore what users say they want, but to also sometimes ignore the feedback they give as well. If initial feedback from users were heeded, consumers today would not have the VCR, fax machines, 24 hour news channels, minivans, and numerous other 'innovative' products that have taken the markets by storm (Martin 1995).

Table 6. Techniques to gather user needs and requirements

Technique for Requirements Generation	Identified or reported by	Main idea	Advantages	Disadvantages
Sources of Ideas	Conway (Conway and McGuinness 1986)	Six chief sources of ideas or descriptors surrounding the method	Helps identify which types of sources the industry finds most productive	Can lead to confusion to those who do not understand use of terminology.
Subject Matter Experts	Dahan (Dahan 1998)	Persons with experience in the area are able to articulate end user needs	Bring vast experience to knowledge area; have intuitive feel for subject area	Information is at risk of becoming 'old', especially the longer that the individual is no

				longer practicing in the area of expertise.
Lead Users	Von Hippel (vonHippel 1982), (vonHippel 1988)	Learn about new product innovations / requirements though users	Can give you a lead on the competitive market	Difficult to identify, even across industries
Quality Function Deployment	Clausing (Clausing 1993)	Systematic way of mapping needs to requirements	Quickly identifies requirements and areas of conflicting requirements	Not always repeatable. Same constraints can lead to different solutions. Dependent upon day and people participating
Conjoint	Dahan (Dahan 1998)	Identifies relative worth of needs in relation to each other	Quickly identifies those requirements of greatest worth	Increasing complexity and size of project makes this method unwieldy. However, variations of this method seem to work.
Pugh Method	Pugh (Pugh 1996)	Pools best ideas of competing concepts together to determine a better product	Very simple to use and understand	Must identify a common datum to reference; pooled concept may not be realistic
Kano analysis	Dahan (Dahan 1998)	Categorization of user needs	Allows product development to focus on delivering the 'must haves' and also the 'delighters'	Difficult to initially categorize and must manage costs to improve 'delighters'.
Repertory Grids & Perceptual Maps	Dahan (Dahan 1998)	Categorization of user needs	Identifies by shear volume of comments areas of concern for product developers	May miss other tacit information due to classification scheme
Empathic Design	Leonard, Rayport (Leonard and	Identification of 'hidden' needs	Scaleable across complexity of	Difficult to abstract

	Rayport 1997)	through unobtrusive observation of user and environment	product development dimension from incremental to market creation	information from several 'point' observations and generalize them for the mass market
Focus Groups	Dahan (Dahan 1998)	Structured session where users can interact with one another to identify and articulate their needs	Information can be collected quickly and multiple points of view representatives	Can degenerate into groupthink. May not be helpful in highly sophisticated and technical fields.
Interviews & Surveys	Dahan (Dahan 1998)	Individual specific and focused contact with users to identify needs	Direct contact and feedback to users	Intensive collection effort required. The number of people that need to be interviewed for the sample to be representative may be larger than anticipated
Cultural Anthropology	Takahashi (Takahashi 1998), Dahan (Dahan 1998)	Observations of users in their environment to find hidden needs	Very focused in areas of interest, most practitioners are very skilled and trained	Labor and time intensive - immersion into users environment takes longer than other methods
Toolkits	Von Hippel (vonHippel 1999)	Building Blocks of different items that a user can creatively use to develop a new product	Users more likely to prefer product they helped designed	Difficult to find correct 'Building Blocks' that users understand and can use

Tools for the Front-end of Product Development

In addition to the techniques to elicit and evaluate user needs, there are tools available to specifically document the needs, their translation into requirements, and their evolution to an end state. These tools are specifically for the overall activities of the overall process in the front-end. These tools also become enablers for an effective process in the front-end, when used correctly. Among the enabling tools available today are the hundreds of modeling and simulation tools. They are too numerous to

elaborate upon; however, their place in the overall process is critical[9]. The tools listed in the table below are enablers specifically for the development of the requirements from the user needs. They help quantify what the user means and help translate those needs into testable and understandable requirements. Appendix C contains a detailed discussion about the tools in the table. Note that this list contains just some of the tools that are commercially available for this specific purpose; it is not intended to be all-inclusive. Information about each tool is summarized in the table below.

Table 7. Tools and Technology Enablers for the Front-end of Product Development

Tool Name	Reviewed or Developed by	Overview
IRSS	Booz-Allen & Hamilton Inc. (Booz-Allen & Hamilton 1999)	Requirements Management System for US Air Force
Caliber RM	Feibus (Feibus 1998)	Client/Server Requirements Management System
IcCONCEPT RTM	Birkler (Birkler 1999)	Client/Server Requirements Management System
DOORS	Birkler (Birkler 1999), Feibus (Feibus 1998)	Client/Server Requirements Management System
Executive Information Systems	Expert Choice, Inc.(Expert Choice 1999)	Decision Support Tool
DOME	Wallace (Wallace and Wang 1999)	Collaborative Design Environment

Summary

The main issues contributing to success are having a process that is holistic in nature and takes into account many broad objectives. The process should avoid waste in all forms, including those areas not typically thought of as waste. Development teams play a large part in the success of the front-end along with the interaction they have with an executive review committee. The vehicle to communicate with the executive review committee is one that is also holistic in nature – a business plan. The business plan should address all aspects of the new product from requirements to the organizational and financial impacts the project will bring to the enterprise.

There is not one way to collect, evaluate and understand user needs nor to translate them into product requirements. The method chosen to do so depends upon the circumstances the enterprise finds itself

[9] For more information about Modeling and Simulation and their criticality in the front-end of product development, see (Walton 1999).

in and upon the environment in which it must operate. Each method has its advantages and drawbacks. Clearly, some methods are better suited to some front-end processes than others and the ones chosen to be used are done so with its advantages and drawbacks in mind. It would be reasonable to use multiple methods of gathering requirements to counter the disadvantages one method might have.

Finally, using a tool that will facilitate communication among all of the interested parties of the front-end, specifically as user needs are elicited and evaluated, and then transformed into product requirements is essential. Again, the tool chosen for use must be evaluated against the organizational form of the enterprise particularly in light of the tools drawbacks and advantages. These tools underscore the importance of these Information Technologies as enablers to a successful product development process in today's environment.

Literature about the Military Front-end Process

Several pieces of material exist that explain the theoretical foundations of the current system in the military. There is also a great deal of literature proposing how one group or another would 'fix' the system or improve the various front-end processes of the military[10]. Some of the issues addressed are how proposed new concepts might be identified as useful, how new-concept development and long-range planning should be functionally and organizationally supported, and how might new-concept development and long-range planning be implemented and sustained (Lewis 1995). The explicit topic of Requirements is notably absent.

Note: This section describes the official view as contained in the documentation. The "as is" perspective will be presented later.

Review of the Process in the Military

To further understand the context of the process' existing shortcomings, a brief review of the process is in order. In general, the front-end process in the military is one where user needs are transitioned to requirements for a concept and readied for a full-scale investment decision but still maintain the least amount of definition possible to allow for further tradeoffs later (Laubengayer and Spearman 1994).

[10] Currently, it is one of the most volatile issues in the military community and there are efforts underway that could take action at any time and change the focus, scope or mission of the current system.

The process begins when, at some point in time, a DoD entity realizes it is deficient in fulfilling a defined need or an existing task. That need or deficiency begins a journey through several processes that hopefully ends when the deficiency no longer exists. For this study, the term Fuzzy Front End will be used to describe the portion of the product development process for the military that ends where the Acquisition System[11] assumes control of the development of the material deficiency. This is known as Milestone I in the terminology of the Acquisition System. The 'fuzzy front end' process is run and managed differently by the four military services and is executed differently within each service as well.

Three systems interact with each other as part of the overall military product development process. These systems are called the Planning, Programming, and Budgeting System (PPBS)[12], the Requirements Generation System (RGS)[13], and the Acquisition System. The input to the system usually begins at the Planning stage of the PPBS. After this stage, the product development process splits into two different processes: Requirements Generation and the resource allocation portions of the PPBS. Occasionally, there is some interaction between the separate systems, but typically these interactions are brief and not scheduled or systematic.

Ideally, the output of the Planning process is used as a monetary input to the PPBS and also as a basis for written requirements in the RGS. The Requirements Generation System ideally uses and draws upon those needs, deficiencies, and potential solution concepts identified by the Planning Process to develop the written justification and direction for beginning programs for acquisition. The point in time where successful navigation of all three of these processes for a given requirement occurs is known in the military environment as Milestone Zero, or 'Approval to Start Concept Studies'. In simple terms, the Planning Process identifies a deficiency (in the case of the Air Force, the deficiency is listed in its primary product, a document called the Mission Area Plan (MAP)). The RGS then produces a document known as a Mission Needs Statement before the PPBS may set aside money for further concept development. When the money is available, the Acquisition system may assist with concept development. Once concept development finishes, the RGS produces another document

[11] The Acquisition System is the process the military uses in the full-scale development and fielding of a weapon system or other component. It begins with official funding for beginning product development and ends with the retirement of the product.

[12] The system that allocates resources to the various military departments and services.

[13] The official documentation system that represents the users' (i.e. customer's) requirements and/or need for a system.

known as the Operational Requirements Document (ORD). The PPBS sets aside money for launching the development of the system only when the ORD is approved. This is the point in time where the Acquisition System assumes control of the system development. This point in time is called Milestone I or 'Approval to Begin a New Acquisition Program'.

The Acquisition System assigns a category to a weapon system based upon cost. These are usually a combination of development costs and overall program costs. The Requirements Generation System uses the same categories for managing the validation and approval process for Requirements documents for different weapon system programs. For instance, those Requirements with a large dollar cost will be given much greater scrutiny than those Requirements with a minimal cost.

This diagram shows some of the interrelationships between the three processes.

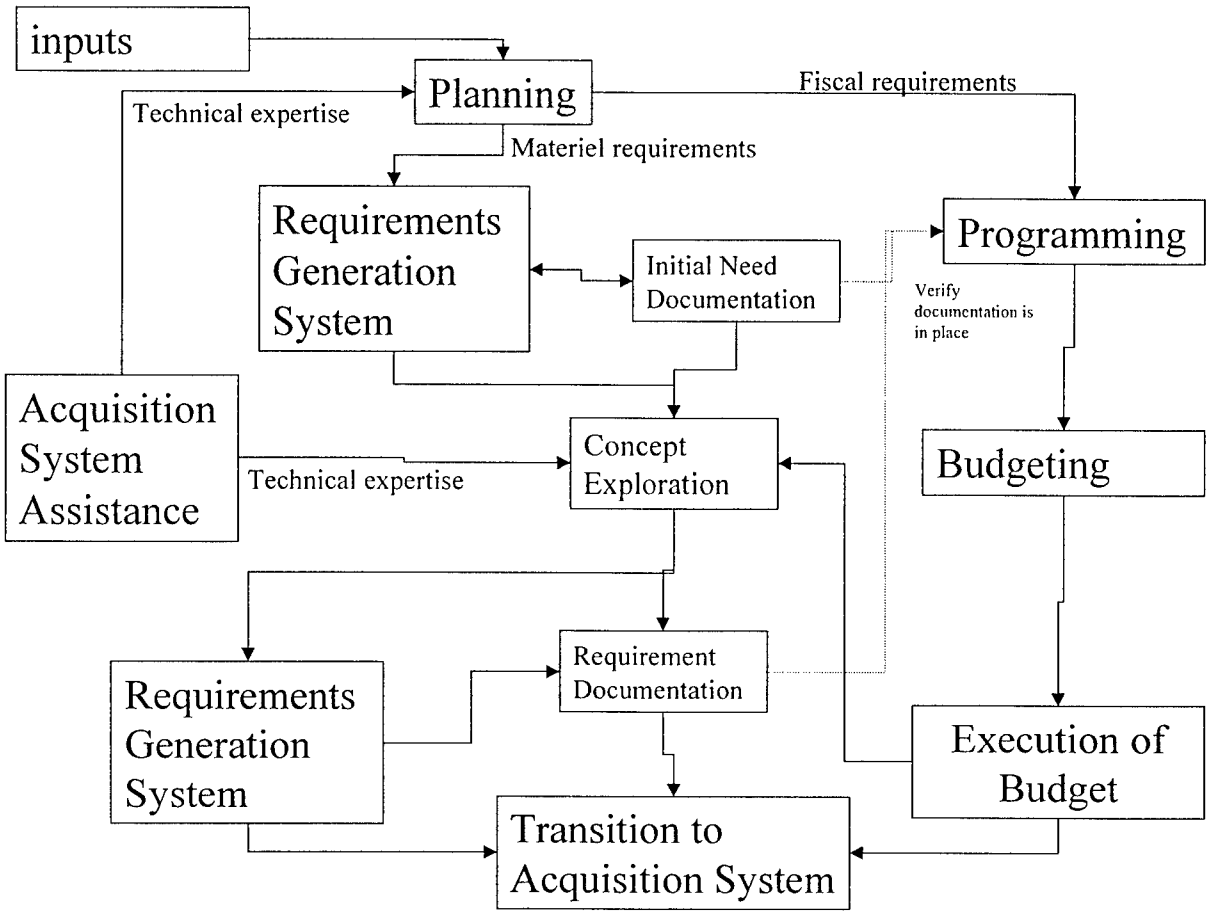


Figure 3. Process Interactions in the Front-end of the Military Product Development Process

The figure above shows another way to depict the interactions between the three systems. A brief overview of the three processes will be given to lay the foundation for further analysis and discussion of the Military Weapon System Development Process.

Details about the Requirements Generation System

Before a potential concept can get resources programmed into the budget or even receive funding, the Requirements Generation System must produce a document that 'validates' the articulated 'need'. A high-level view of the process to generate, validate and approve requirements is presented below.

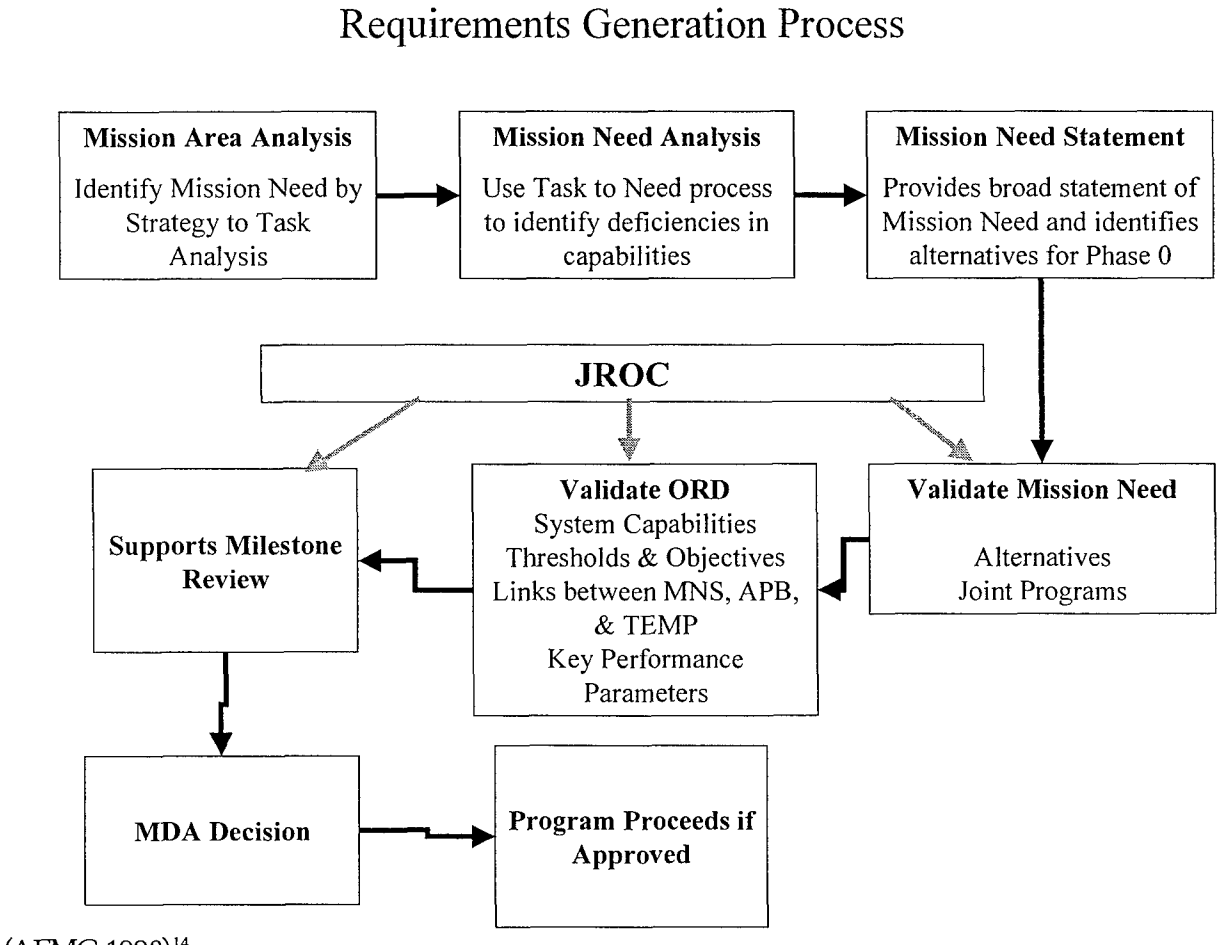
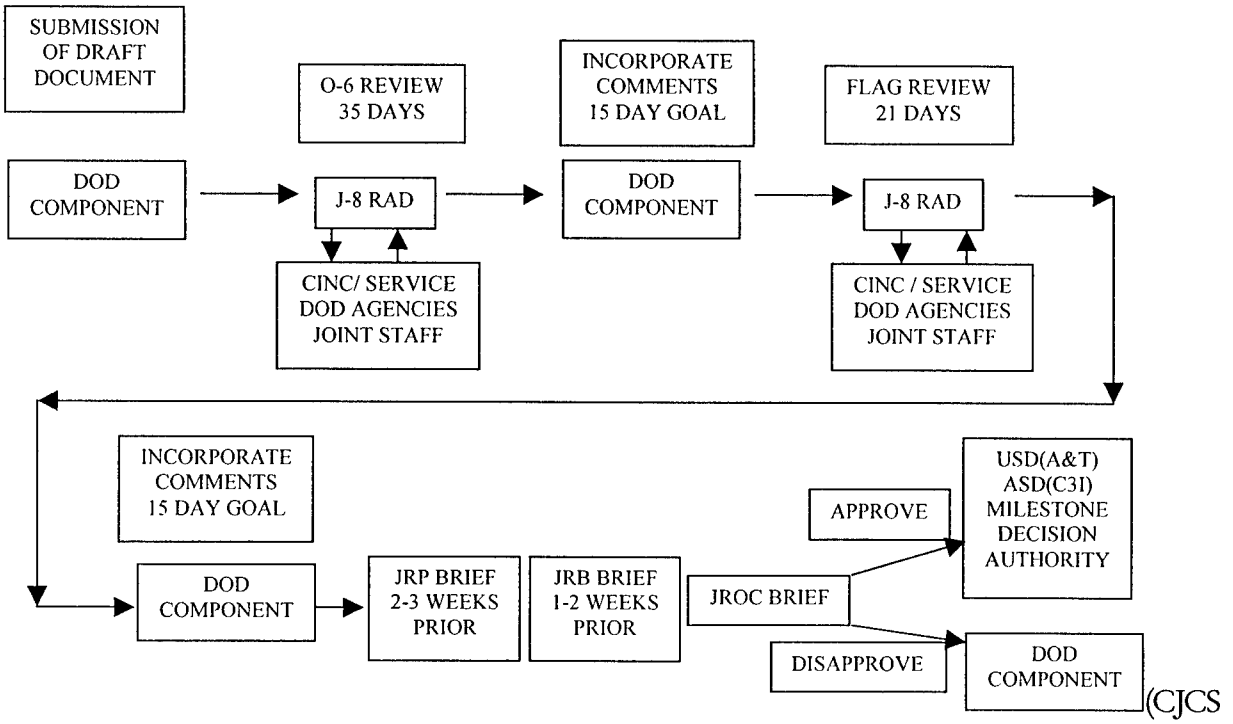


Figure 4. Overview of the Requirements Generation Process

The process is directed by instructions from the Chairman of the Joint Chiefs of Staff. This instruction mandates specific and different activities that are required for the development of capability shortfalls and needs into requirements for weapon system solutions (CJCS 1999). The vast majority of these activities are the responsibility of the different services. These activities that are service responsibilities include conducting a Mission Area Analysis and a Mission Need Analysis. The Instruction directs the format for Mission Need Statements as well as the format for Operational Requirements Documents. It further indicates the validation and approval process to be used when a

[14] See (AFMC 1998) for detailed information about this process.

requirements document needs to come before the JROC for validation and approval. A detailed process flow for the process of validating and approving a Mission Needs Statement is given below.



(CJCS 1999)

Figure 5. JROC Review Process

"The JROC assists the Chairman of the JCS (CJCS) in making decisions and recommendations about which weapon systems and other military equipment need to be developed, bought, modified, or canceled in order to meet the potential combat requirements of the CINCs"(Smith 1999, pg. 28). The members of the JROC are the Vice Chiefs of Staff of each of the military services. In all other areas, the JROC gives the services wide latitude to define and implement processes to develop requirements and the associated documents (CJCS 1999). Virtually all needs and requirements are generated by the different services, although the JROC has the authority to generate new requirements and/or needs (i.e. top-down directed).

The Joint Requirements Oversight Council (JROC) or another service group (as in the case of the Air Force such as the AFROC (Air Force Requirements Oversight Council)[15]) act as the validation authority for these documents - depending upon the kind of requirement. These councils consist of the senior leadership of the services. The JROC has the ability to cancel or delay weapon system development programs if it feels the MNS is not valid. It also has the authority to internally generate military requirements that the other services have not developed (Salazar 1996). The JROC should be seen as being akin to a corporate board of directors that will view military requirements holistically as opposed to being parochial to their services' interests (Salazar 1996). James Blaker, senior advisor to the Vice Chairman of the Joint Chiefs of Staff, and JROC Chairman, indicated the core principle of the JROC was "having the right people address the right issues, over the right amount of time" (As quoted by Salazar 1996).

A new Requirements Document known as a Capstone Requirements Document (CRD) has recently been added to the current system. The purpose of this document is to specify a 'systems of systems' approach to meeting a validated need. The place in the process where the CRD fits is between the MNS and the ORD. "The CRD captures the overarching requirements for a mission area that forms a family-of-systems (FoS) (e.g., space control, theater missile defense) or System-of-Systems (SoS) (e.g., national missile defense). The ORD translates the MNS into more detailed and refined performance capabilities and characteristics of a proposed concept or system" (CJCS 1999).

An example of the purpose for the CRD follows. A need has been validated and approved on some new kind of threat detection system from space. Upon close examination of the MNS need, it is determined that the need cannot be fulfilled through one system. In this case, it may require a series of different satellites in different orbits, along with several ground observation posts gathering different types of data. The need is met only when these systems work together.

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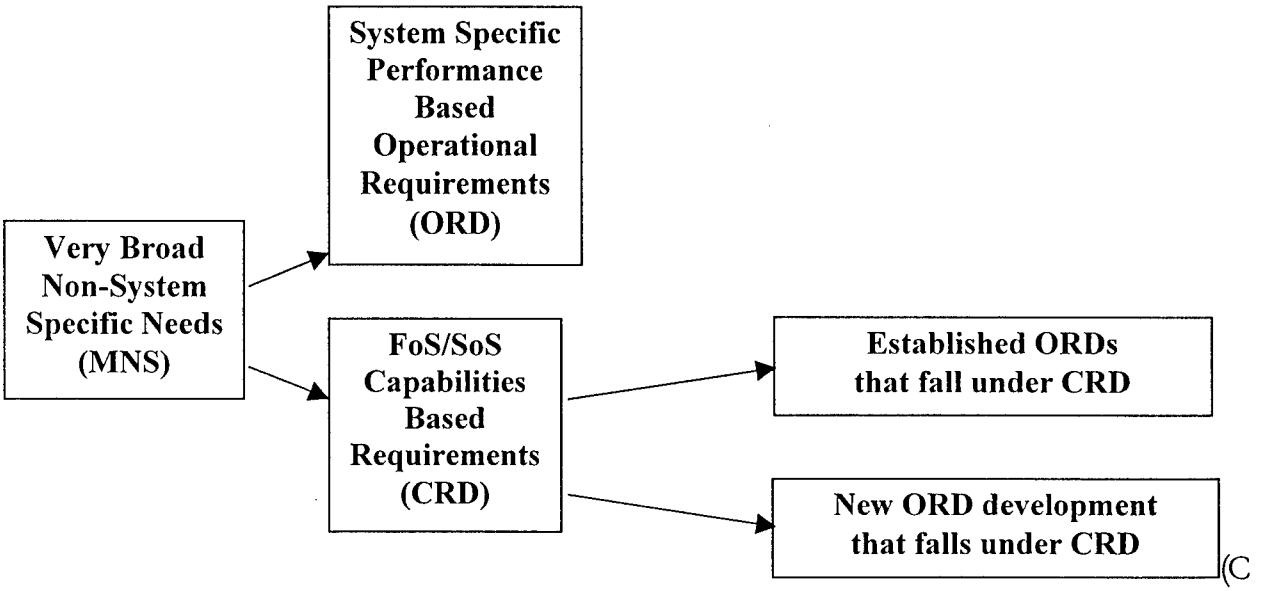
[15] "The AFROC chairperson is the Director of Operational Requirements (AF/XOR). The AFROC permanent members are the MAJCOM Requirements principal O-7/O-8 or civilian equivalent, representatives from SAF/AQ (appropriate directorate), SAF/FM (FMB for funding and FMC for cost issues), the Air Force agency whose need or requirement is under AFROC consideration, AFOTEC, AF/XOI, AF/IL (ILM or ILS as appropriate), AF/XP, AF/TE and AF/XOC. Ad hoc members' participants are based on topics under review. They include: functional expert representatives from AF/SC, AF/SG, and AF/SP (representatives are not limited to O-7s/O-8s or their civilian equivalents). Other service representatives may be present when joint needs or requirements are considered" (USAF/DXOR 1999, pg. 34).

A validated and approved CRD would allow for the development of several ORDs that would contribute toward fulfilling the need. The approval process for the CRD is identical to that used by MNSs and ORDs. The CRD is most appropriate for a Unified Command[16] to write. At this time, there have been very few CRDs approved. For this reason, the CRD is considered out of scope of this effort.



(CJCS 1999)

Figure 6. Evolution of Requirements Documents[17]

The process for the validation and approval process of an ORD does not change according to the 'fidelity of the requirements' or the development state of the program. The revised ORD follows the same process flow that has already been outlined and is changed only to reflect increasing detail about the operational requirements.

Each Unified Commander is tasked to develop an Integrated Priority List (IPL) of requirements from the commander's perspective to fulfill the mission and tasks that the Unified Command must perform. These IPLs are to be used in the development of resource allocations within the services. Should

[16] A Unified Command is made up of warfighting units of the different services working together. All activities among the different units are coordinated toward achieving the overall goal and are led by a single commander.

[17] Examples of generic requirements document (MNS, CRD, and ORD) generation process is found in Appendix E.

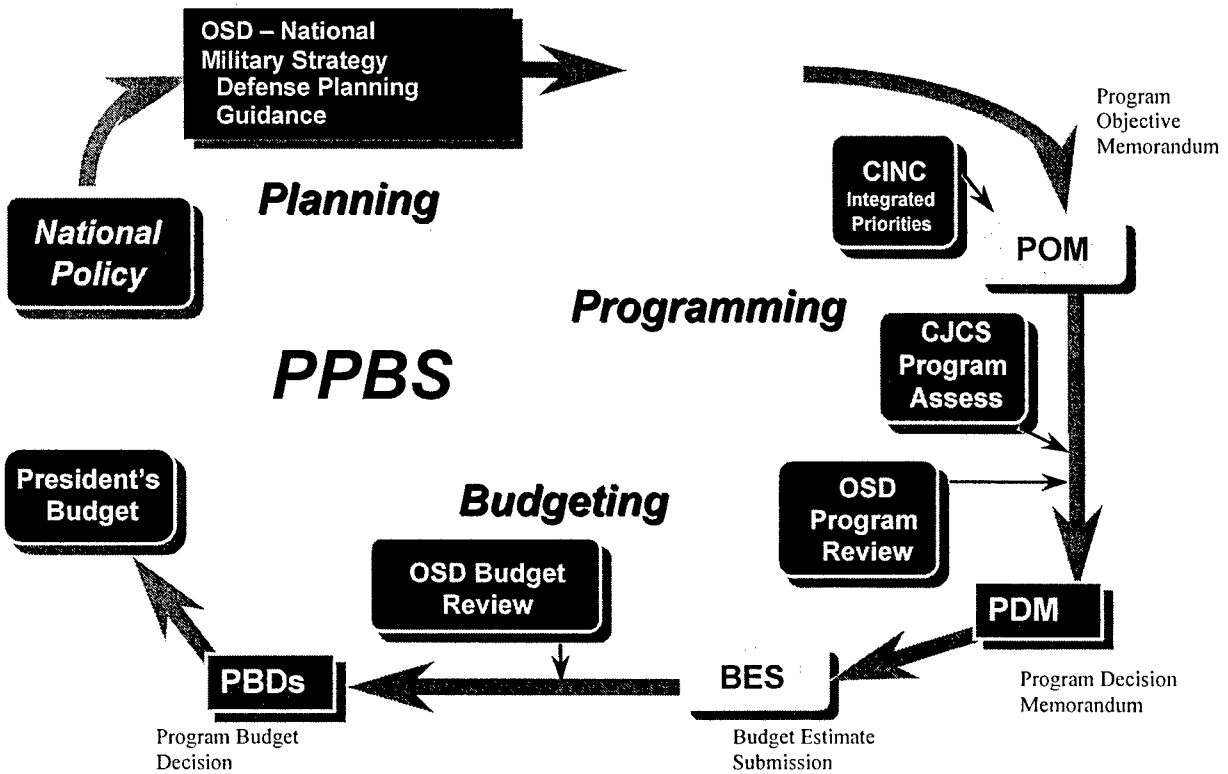
these not be adequately addressed in the services' budgets, the Joint process has a forum called the Joint Warfighter Capability Assessment (JWCA). This forum allows resourcing issues to be aired and debated across the services. This process can directly influence the makeup of a service's budget request. It allows the JROC to also influence the outcome of requirements development (i.e. approving or delaying requirement documents).

A SWARF (Senior Warfighter Forum) has recently been added to the joint process to address issues that specifically relate to requirements and do not 'fit' into the overall purposes of the JWCA process. The SWARF allows Unified Commanders to influence the requirements processes of the services from a joint perspective. "The SWARF is a JROC-directed forum used to organize, analyze, prioritize, and build joint consensus on a complex resource and requirements issue for JROC approval. The JROC tasking memorandum will identify the SWARF lead, specific issue to be addressed, fiscal guidelines, assignment of the appropriate acquisition and technical expertise to frame issue, and timeline to report recommendation(s). The JROC will assign CINCs to lead SWARFs according to their missions and responsibilities. The SWARF lead will brief the recommendation(s) to the JROC" (CJCS 1999).

Details about the PPBS

The Planning, Programming, and Budgeting System is the method by which the military plans and funds its operations. Although the money for the defense department is budgeted by Congress and signed into law by the president, the actual process of building these budgets falls upon the Defense Department – although the Congress may determine to change things during its deliberations. There is added turbulence to this process as Congress requires the DoD to submit a budget each year for the next two-year period. Therefore, there are always multiple cycles of the PPBS working at any given time of the year. The Congress has never enacted a 2-year budget for the military, but the DoD continues to comply with the legislation requiring it to submit two years of budget requests. The process itself requires approximately two years once the Programming Phase begins to navigate through all the phases to reach the final Department of Defense Budget. Each service goes through this process of planning for the future, programming (estimating) future budgets, and actually submitting a budget request. The Defense Department then consolidates these requests into a single budget request. Within the Air Force, each MAJCOM is responsible for all phases of the PPBS,

although each MAJCOM receives written guidance from the Headquarters Air Force about each stage of the PPBS.



(Plummer 1999)

Figure 7. The Planning, Programming, and Budgeting System

The Planning Phase begins by using the National Strategy as communicated by the President of the United States. The Office of the Secretary of Defense (OSD) translates this strategy into the National Military Strategy. Additionally, OSD releases its bi-annual Defense Planning Guidance. The individual services release other strategic and planning documents, as they deem necessary. All of these documents are used to determine the current capabilities of the services and also to help reveal capability shortfalls.

The governing instructions regarding planning also mandate the use of a RAND-developed[18] methodology called 'Strategy-to-Task' to articulate the needs, deficiencies, and potential solutions that may exist in a mission area. The diagram below represents this methodology using a building block approach, with each segment supporting the one above it.

(Stewart 1996, pg. 7)

Figure 8. Strategy-to-Task Hierarchy

As shortfalls are uncovered, the Planning Phase, with portions of the Acquisition community and Requirements Community, determine exactly how the service plans to correct those deficiencies and/or assume new mission areas as outlined in the visionary and strategic documents. At the end of the Planning Phase, the theoretical visions of the planning phase are represented by cost estimates for

[18] RAND is a Federally Funded Research Development Center (FFRDC).

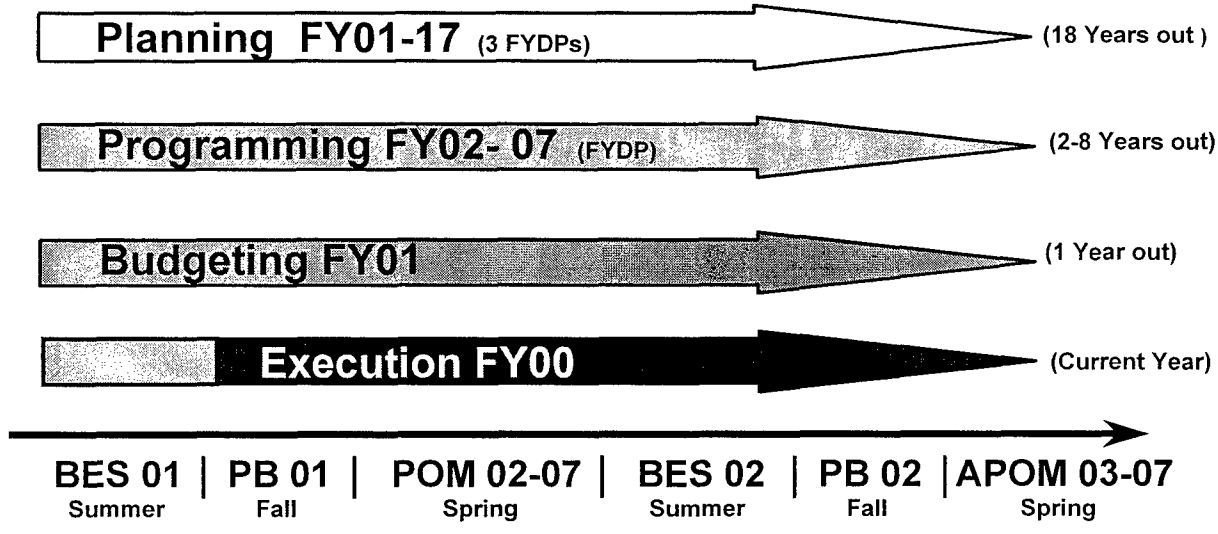
future budgetary action. The major products from this phase are some financial plans and documents to implement the vision and strategy given. One of those documents is the Future Years Defense Program (FYDP) Plan. The FYDP Plan covers a period of 6 years beyond the immediate year in the future. Theoretically, there is no limit to the number of FYDPs that can be listed and maintained. However, current guidance calls for maintaining only the next 4 sets of FYDPs. The Planning Phase does not deal with the most recent FYDP; rather, it deals with the FYDPs that extend up to 18 years in the future. Other important products are the descriptive narratives surrounding each of the deficiencies and proposed solutions. These narratives are called Mission Area Plans (MAPs) in the Air Force and are used as inputs to the Requirements Generation System.

During the Programming Phase, the near-term FYDP is the focus. The first two years of the near-term FYDP are further developed into the other major product of this phase - the Program Objective Memorandum (POM). For example, every year each Air Force MAJCOM develops a yearly input to the overall Air Force POM. Each services' POM is reviewed by the Chairman of the Joint Chiefs of Staff. The Chairman produces a document called the Chairman's Program Assessment (CPA). It is an assessment of the services' POMs, contains alternative recommendations to the service's POMs, and prioritizes requirements from the warfighting CINCs, which is delivered to the Secretary of Defense to assist the Secretary in making decisions on the DoD budget. The Secretary will also review each of the service POMs independently. The Secretary will take inputs from the CPA, the services' POMs as well as other advocacy sources, like the Defense Planning and Resource Board. The Secretary will release a Program Decision Memorandum (PDM) that contains the decisions of the Secretary regarding the services' POMs (Salazar 1996).

The last phase of the PPBS is the Budget Phase. This phase begins when the services prepare a Budget Estimate Submission (BES) based upon the PDMs received from the Secretary of Defense. These BESs are submitted to the Office of the Secretary of Defense (OSD) and the Office of Management and Budget (OMB) for a budget review. The CPA also exerts a great deal of influence upon this phase. Upon completion of the budget review OSD releases a Program Budget Decision (PBD) back to the services so that the services can modify their BESs for inclusion in the President's Budget (PB) to Congress (Salazar 1996).

Throughout all of these process phases, there are political maneuverings going on during the budget building exercises. Furthermore, the Program Element Monitors (PEMs), who manage a budgetary funding line item (such as planes, trucks, tanks, etc.), often engage in helpful '11th hour horsetrading' to help fund items important to their warfighting customers. Terms such as Offsets and other budgetary language will not be discussed in this effort, as it is beyond the scope to do so. However, these individuals are most often responsible for building the budgets year after year. They are, albeit unofficially documented, very important parts of the PPBS process.

Again, as these processes exist, they are not static. At any given time there are four different sets of PPBS activities. The following diagram illustrates this concept.

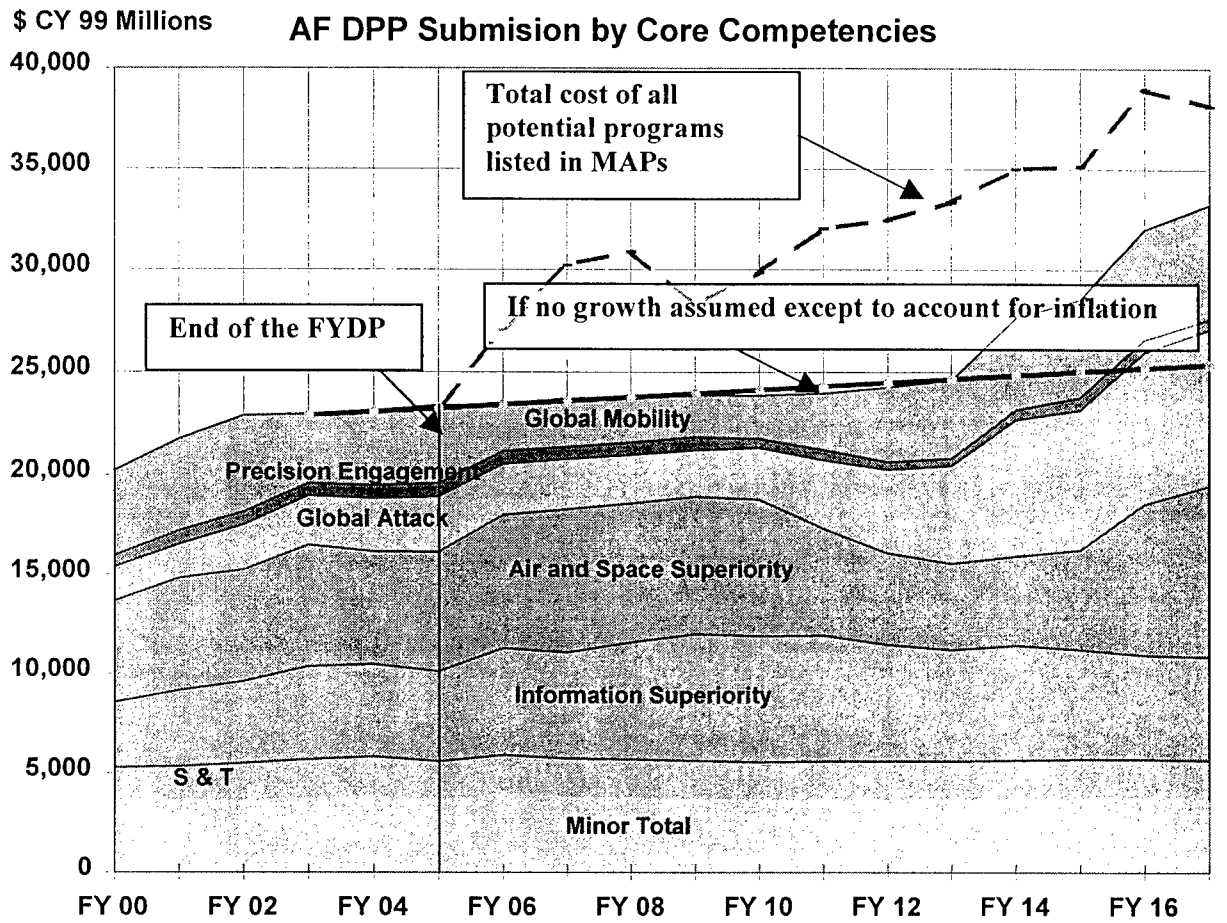


(Plummer 1999)

Figure 9. Visual Representation of the Overlapping Phases of the PPBS

The programming and budgeting side of the PPBS drives the outcome of the entire system. Without money set aside to fund the development of a system or the continuation of existing programs, these things would quickly halt.

As an example, the following graphic[19] shows the current funding levels for the Air Force (programmed as of 1998) through FY17 as well as the implications of the output of the Planning processes. FY stands for Fiscal Year (from October to September) and CY stands for Calendar Year.



(Imlay 1998)

Figure 10. Air Force Defense Planning Process Submission by Air Force Core Competencies

After all of the plans have gone through several iterations to bring the estimated costs within the budget guidance for the POM inputs, the years beyond the Future Year Defense Plan (current year through the next 4 years) show the increased costs to finish each program. "Since the POM years

[19] The heavy dashed line beginning in FY05 represents the total inputs from each command's MPP. The slowly increasing line represents a real 10% assumed growth in budget allocation. By FY13, programs already approved for funding and in the funding stream outstrip available resources. There is no room for additional projects or new starts beyond this date.

{cannot} be affected, this create{s} a bow wave effect starting the year after the POM and continuing throughout the planning horizon" (Weishoff 1990, pg. 42). This graph shows the infamous 'bow wave' effect[20] caused by stretching, postponing, and changing programs from their initial plans. For more information about the cost of these changes, see the "Cost of Delay Analysis" section of (McNutt 1998).

The Requirements Process does not remain dormant after a Mission Need Statement has been approved; nor does the PPBS. This is because prior to each Milestone, a new or revised ORD must be validated and approved and money must be properly programmed and budgeted.

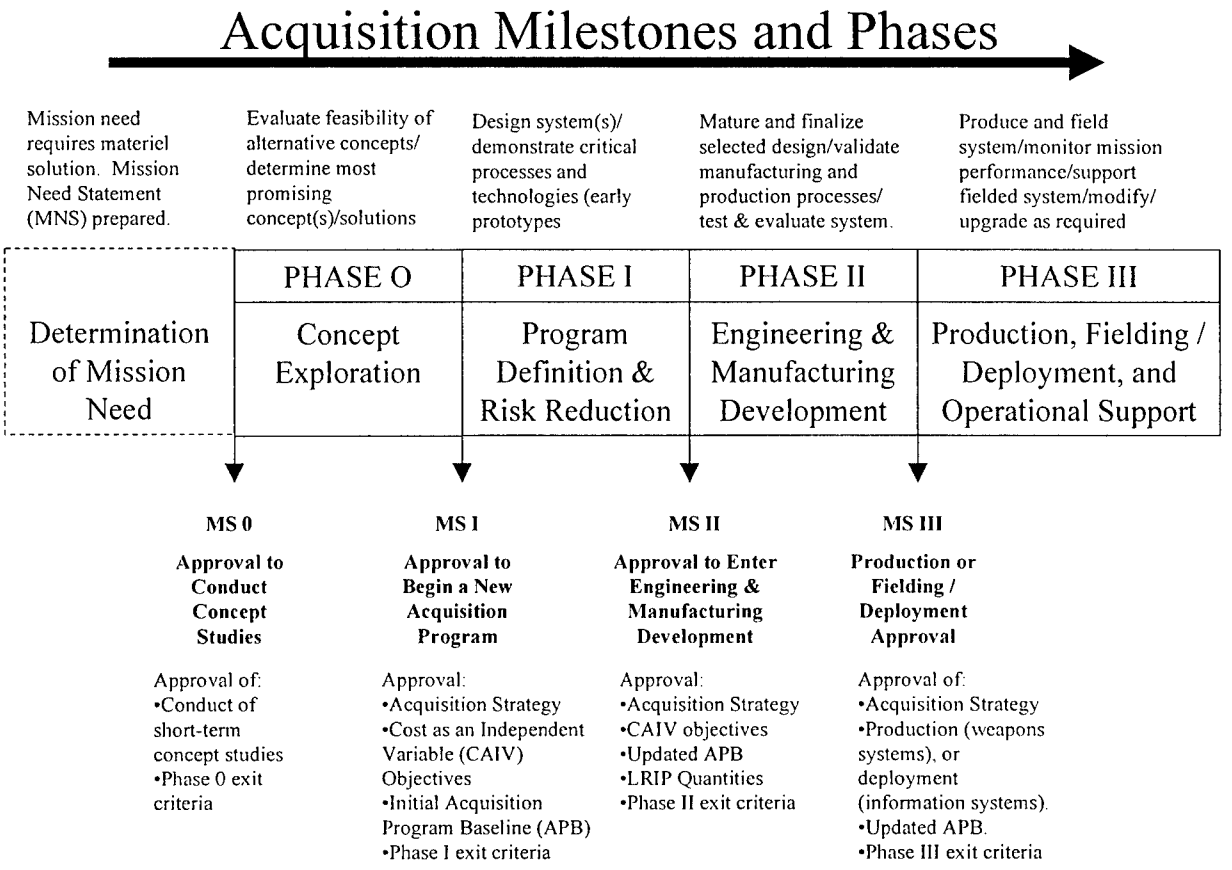
Details about the Acquisition System

For most military observers and also military personnel, a weapon systems development program begins only after getting through the above mentioned processes and entering Phase I of the acquisition system. The typical acquisition process consists of 5 phases that are broken up by milestones. Two of those milestones, Milestone 0 and Milestone I, have already been mentioned. Acquisition System participation is limited in the pre-milestone zero phase and Phase Zero.

The main activity of the Acquisition Process during this time is related to the interface where the Process assumes control of the development from the Requirements Process (briefly at Milestone 0 and then at Milestone I). This occurs when an Acquisition Executive is named as the Milestone Decision Authority (MDA) and makes a decision about the program. The delegation of this authority comes from the Secretary of Defense and has been vested in the Defense Acquisition Board (DAB). The DAB is made up of senior acquisition personnel (civil and military). The DAB will often delegate its authority to the services or to an individual, who is called the MDA. When the MDA believes the exit criteria established for the Milestone have been met, and money has been set aside for the program, the MDA can approve completion of the milestone. Upon approval, the process is allowed to proceed into the next phase of development. Nevertheless, at Milestone I or Program Initiation, the Acquisition System becomes the primary driver.

[20] Refers to the existence of the large budgetary shortfalls just beyond the 5-year funding horizon. The bow wave analogy comes from the notion of a moving surge prior to the bow of a moving ship. In this case the short fall moves yearly just beyond the limits of the current 5-year plan.

The diagram that follows depicts the DoD Acquisition Process.[21]



AFMC 1998)[22]

Figure 11. Overview of Acquisition Milestones and Phases

All programs initiated by the Department of Defense have an Acquisition Category (ACAT) assigned. Usually, size and complexity categorize acquisition programs. These categories play a major role in the validation and approval of Requirements Documents in the Requirements Generation System because a document's ACAT determines where the validation and approval authority lies. The JROC automatically reviews all ACAT I documents and has delegated validation and approval authority for lower ACAT documents to the respective service chief. There are three major acquisition categories. They are:

[21] For a detailed review of the current military product development process, see (McNutt 1998).

1. Acquisition Category (ACAT) I (usually MDAPs (Major Defense Acquisition Programs))
2. ACAT II (usually major systems)
3. ACAT III (all other acquisition programs)

ACAT I programs are programs that are: "(1) designated such by the Under Secretary of Defense (Acquisition and Technology) (USD(A&T)) as an MDAP, or (2) estimated by the USD(A&T) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $355 million in fiscal year (FY) 1996 constant dollars or, for procurement, of more than $2.135 billion in FY 1996 constant dollars (**10 USC §2430**[23])" (DoD 1996).

"ACAT II programs are defined as those acquisition programs that do not meet the criteria for an ACAT I program, but do meet the criteria for a major system, or are programs designated ACAT II by the MDA. A major system is a combination of elements that shall function together to produce the capabilities required to fulfill a mission need, including hardware, equipment, software, or any combination thereof, but excluding construction or other improvements to real property. A system shall be considered a major system if it is estimated by the DoD Component Head to require an eventual total expenditure for RDT&E of more than 135 million in FY 1996 constant dollars, or for procurement of more than 640 million in FY 1996 constant dollars, or if designated as major by the DoD Component Head (**10 USC §2302(5)**[24])" (DoD 1996).

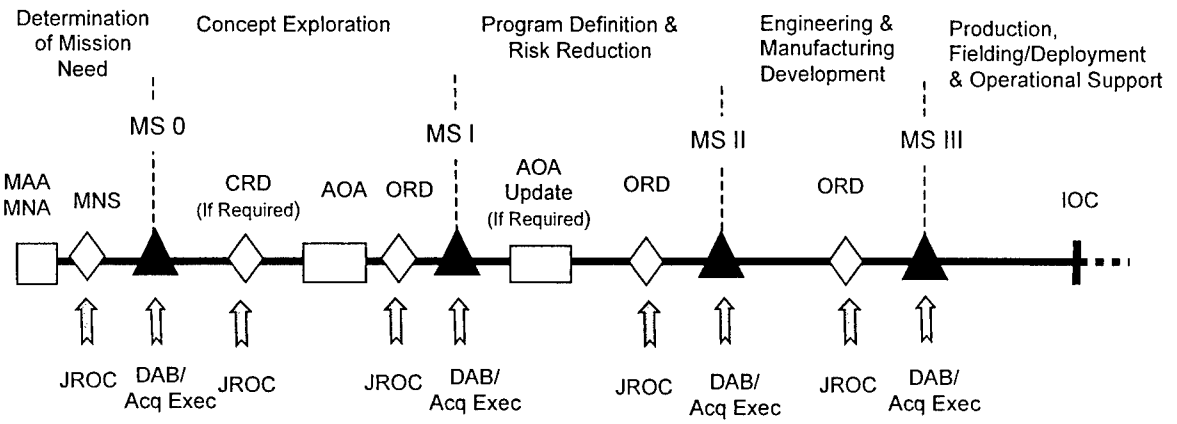
ACAT III programs are acquisition programs that do not meet the criteria for an ACAT I, or an ACAT II (DoD 1996).

The following diagram shows the relationship between the Requirements Generation System and the Acquisition System. The Requirements Generation System usually completes its activities prior to the Milestone decisions.

[22] For more information about the above diagram, please see (AFMC 1998)

[23] Title 10, United States Code, 2430, Major defense acquisition program defined (these amounts have been increased pursuant to the statutory notice provided to Congress)

[24] Title 10, United States Code, 2302(5), Definitions



(CJCS 1999)

Figure 12. Requirements and Acquisition Interfaces

The diagram shows virtually the entire process to include the further steps beyond the initial MNS and ORD generation. As shown above, the overall Product Development process of the military includes mandatory ORD revisions and multiple AoAs (when determined necessary by the DAB or MDA at each milestone).

The Benefits of an Advanced Front-end Process

Based upon the literature and studies evaluated, the benefits of having an advanced front-end process are tremendous. Saving $20.5 Billion per year (figure normalized to the FY2000 $267.2 Billion DoD Budget) according to the realistic estimate made by Ganzler, and cutting the overall cycle time for the front-end process will bring substantial savings to the defense establishment. Potential savings for the Air Force alone amount to approximately $6 Billion per year in savings (based on FY2000 Budget). Furthermore, an advanced front-end will provide higher quality requirements and higher fidelity data for decision-makers. An advanced front-end is more apt to produce projects that are more likely to succeed and are more likely to correctly capture the desires of the end user/customer. Products will meet the needs for which they were designed to fill. Cost growth and requirements creep will be easier to control. Projects will proceed through product development processes smoother and easier.

Drawbacks to current literature

Other than the limitations already discussed previously, commercial sources generally don't look at large, capital intensive, complex, and technologically advanced products. The only exceptions to this

rule are those sources dealing specifically with the military application. Yet, none of the military sources connect the applicability of commercial processes and experience in dealing with the uncertainties of the front-end to those faced by the military today.

In the commercial world, the Product Development topic is huge, yet front-end research is only now starting to emerge. This is an area of great interest and widespread application. For instance, Rosenthal's material has already been cited in a journal used by the Chemical industry (as being outside the normal frame of reference). Cooper's work has already been cited numerous times. Others including Wheelwright, Clark, Christensen, Reinertsen, Smith, Rosenau, etc., continue to expand the knowledge of this area.

There are two other studies of the Military Requirements Process underway. One study is entering the final stages of its work (as of this writing). Its first report was issued in September 1999 (USAF/DXOR 1999). The final report should be issued in early summer 2000. The General Accounting Office of the US Congress is conducting the other study. It should present its findings late in the fall of 2000. Both of these reports are similar in design as they assess the state of military requirements generation and compare these to commercial practices in order to find and determine Best Practices in Requirements Generation. It is hoped that these studies will not have the same shortcomings of the previous military literature. In order to do so, they should take into account large products, a distributed ownership base, political forces, different 'customers' within the enterprise, and incorporate the latest research material produced by academia and in use in the commercial world.

Preliminary Conclusion

A systemic approach or holistic approach to the front-end of weapon system development is needed. It should be in harmony with lean thinking and principles. The correct mix of processes, organizations, and tools will embody the purposes and definition of lean in new product development's front end and lead to successful product development practices. As Acquisition Reform has made a definite mark upon the way the military does its business, other areas for reform have emerged. Based upon the current status of the system, the emphasis for reform in the military must shift to the front-end of weapon system development.

CHAPTER 3 - FRAMEWORK FOR UNDERSTANDING THE FUZZY FRONT END

Up to this point, this work has described issues surrounding the front-end of Product Development. As a general observation, the process area prior to business case decisions or the military Milestone I is still somewhat vague and unexplored. This section presents a framework based upon literature by which organizations can compare their front-end process against an idealized front-end process. Additionally, some useful metrics are given that will help to measure the performance of each organization in any area of the framework. The idealized front-end process is by design presented at a high enough level so that regardless of the naming conventions used, it is applicable to the individual needs and processes of diverse organizations. The framework also contains a maturity matrix by which an organization may determine where the state of its processes lie verses that of an idealized process. Furthermore, both the framework and maturity matrix seeks to address the specific shortcomings existing today in both the military and commercial processes.

This framework quantifies and clarifies the paradox of organizations that are using the most relevant and useful methods of gathering requirements - methods such as Quality Function Deployment, Conjoint Analysis Techniques, and many others - but still are unable to capitalize on the discovered opportunities in the front-end. Non-exclusive examples of this include being late to market, failing to pursue potentially good product ideas, and producing a product that is vastly different than that envisioned during the initial stages of development (a.k.a. requirements creep).

The framework consists not only of an ideal process for the front-end of Product Development but also enablers that contribute to the successful navigation of the process. The framework embodies a 'holistic' process, from implementation to integration with other core business processes. The Process for the front-end of product development has four main activities or stages. The actual appearance or names by which these activities are called within companies is likely different, but the purposes of these activities are nevertheless the same. The Enablers or Process Enablers can be broken down into two specific areas: the Business Foundation Enablers; and the People, or Organizational Enablers. This process diagram espoused by the framework is similar to the work done by Cooper and also

Conway and McGuinness but expounds upon the other material presented in this chapter and is more comprehensive than their contributions (Conway and McGuinness 1986; Cooper 1988).

First, an overall view of the process will be given and an explanation of the activities in each area. Following this, the process will be examined directly in light of the two different Enablers – where and how they apply. Metrics and measures of performance will be given.

Finally, a relative scale of process maturity and application of Enablers will be presented. This framework will be used to evaluate the case studies discussed in subsequent chapters and also to compare them with each other. Validation of this framework will come from using the results of two other known studies/frameworks that attempt to evaluate/measure portions of the front-end.

The Process

Cursory glance at a graphical depiction of the overall process flow bears a striking resemblance to a feedback matrix. The principles of feedback certainly apply here. The activities in these stages imply a highly iterative, tightly coupled mode of operation. The detailed nature of these activities is discussed below. Each process step relies upon the output of the previous step to proceed, but can also influence any or all of the previous steps in the process. Although the framework is discussed in a serial fashion, it should be noted that the activities of the framework are continuous and have only been presented in this fashion to facilitate understanding.

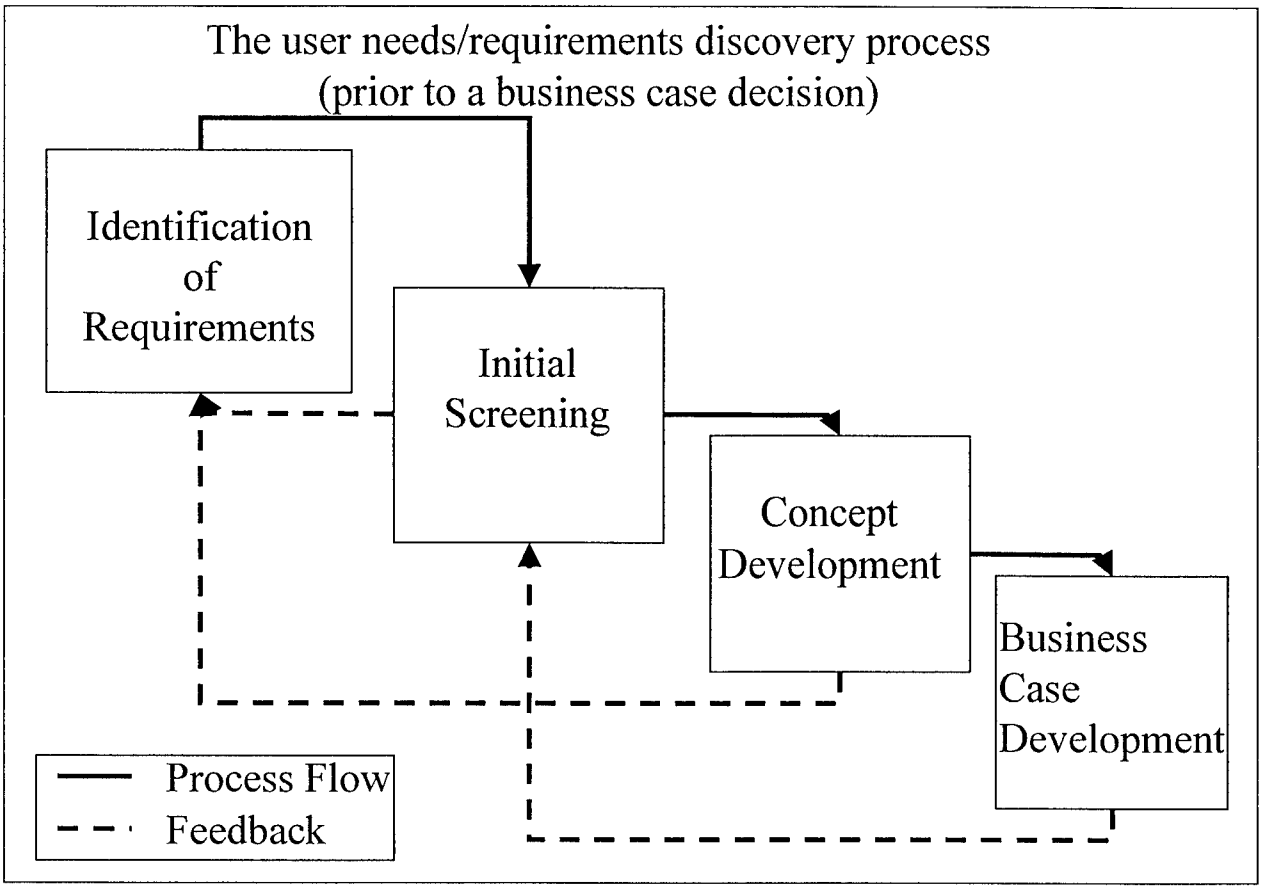


Figure 13. The front-end framework

Identification of Requirements

The first step in the process of getting Requirements and User Needs can be called Identification. The sources of information upon which the identification of user needs and customer requirements is based are extremely varied. It is essential that any process design is robust enough to accept information from multiple sources. A few examples include inputs from the marketing function in the organization, the planning and technology development functions, direct feedback from existing customers and information gathered from the market (i.e. either appraisal of competitor's activities as well as trends within the marketplace) (Frohmna 1978; Cooper and Kleinschmidt 1987; Leonard-Barton, Wilson et al. 1994; Cooper 1997; Khurana and Rosenthal 1997; Tabrizi and Walleigh 1997; Khurana and Rosenthal 1998).

The inputs to this stage are the sources of the need and/or requirement. These sources are extremely varied and are not confined to a specific list. However, the inputs can be things such as direct

consumer feedback, market studies, research, and surveys, lead users, marketing department ideas, top-down management vision and direction. There are multiple ways to search for these inputs as well. Understanding the different methods will allow an organization to structure its input gathering methods in a way most suited to its front-end process and is also properly targeted and directed to the correct sources of information (Conway and McGuinness 1986).

The main process at work is one that sorts, prioritizes, and understands the various process inputs. There are several methods to do this, such as using QFD, Conjoint analyses, Pugh analysis, simple categorization schemes, etc. The key to this stage is using the proper kind of a structured method. Furthermore, there may be multiple methods that should be used based upon the strengths and weaknesses of each method (Dahan 1998). However, regardless of the approach taken, it should be one that is consistently used and correctly applied.

The primary output from this stage is an idea of the true needs and requirements that must be fulfilled. These are typically documented in some form and are done in a manner that communicates to a decision making forum the necessary information, such as potential concepts, rough costs (for development, production, and lifecycle), existing risks, and required technologies. However, the most robust type of communication is one that does not specifically favor particular solutions, nor solutions favored by the vision of an important customer, but should describe the desired end-state or desired capability (Buede 1997).

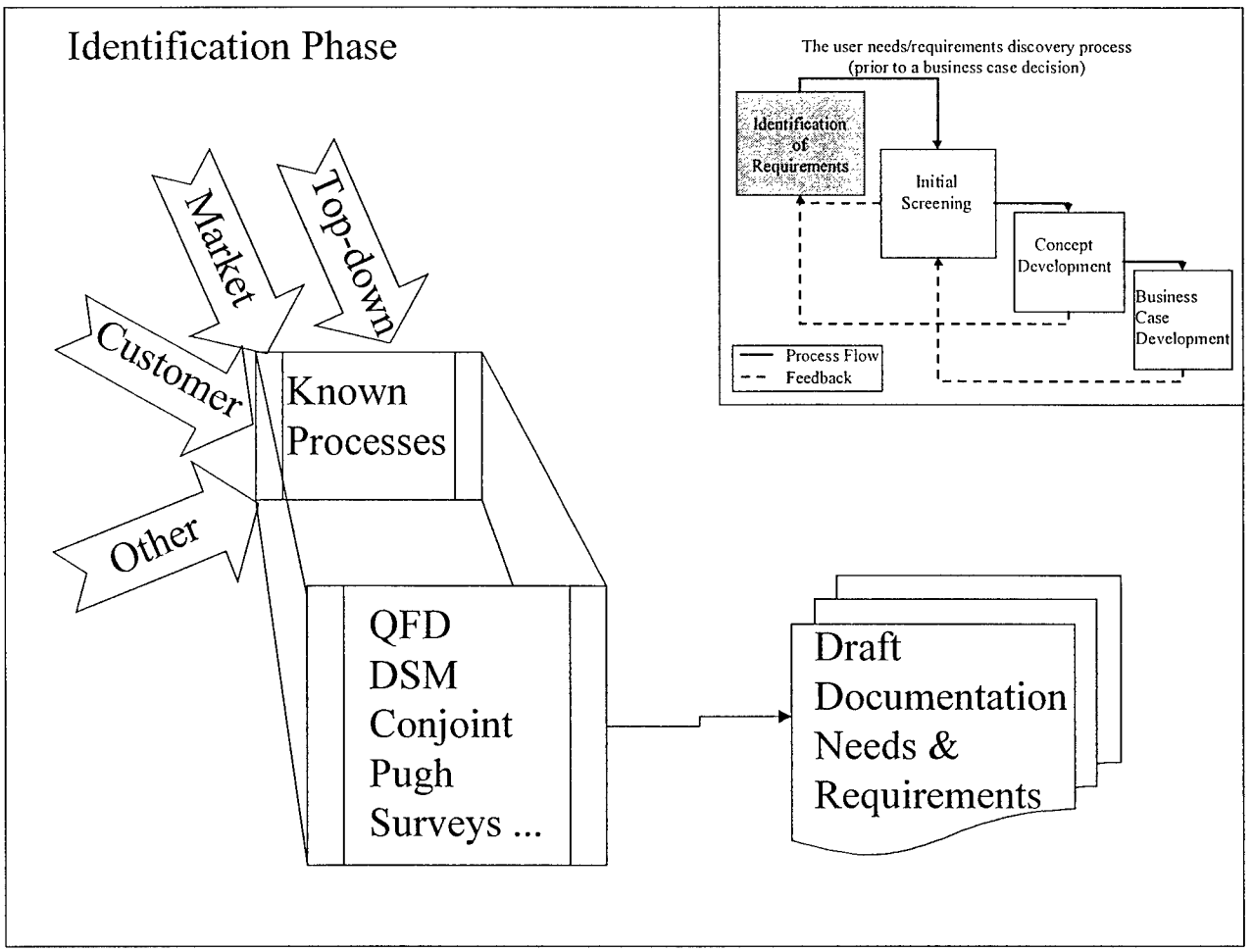


Figure 14. Visual representation of the Identification of Requirements Phase of the Framework

Some of the specific enablers of this process are the structured methods that help discover needs and requirements that aren't necessarily apparent. There are many methods available to do this. Some of them are Quality Function Deployment, Conjoint Analysis and derivations thereof, Pugh Analysis, Kano Analysis, and many others (Conway and McGuinness 1986; Kalyanaram and Krishnan 1997; Dahan 1998; Dahan 1998). Therefore, one of the first necessary items that are required in this step is a structured forum that helps with the elucidation and documentation of user needs and requirements (Buede 1997).

The ideal outcome of this step is ideas that come in a steady stream. A goal of this step is to foster innovation or to provide a steady stream of new products to replace those that have become or soon will become obsolete. Some of the metrics for this stage are the cycle time from beginning to end of

this stage, customer satisfaction of the results of this stage, possible patent ideas/inventions/copyrights, and also a stream rate (number of 'ideas'/time) going through the process.

Key to the success of this stage are certain organizational and business elements. Among the organizational issues required are the teams that develop these ideas and user needs. Teams should be small and cross-functional (Smith and Reinertsen 1992; Moenaert, Demeyer et al. 1995; Khurana and Rosenthal 1997; Khurana and Rosenthal 1998). Business information, such as the core competencies of the organization along with items such as the vision of the company need to be well communicated (Cooper and Kleinschmidt 1987; Khurana and Rosenthal 1997; Tabrizi and Walleigh 1997; Khurana and Rosenthal 1998). Finally, tools and methods must be used that promote communication of ideas to the next stage (Cooper and Kleinschmidt 1987; Khurana and Rosenthal 1998). Without these elements in place, it is likely the other activities in this stage, even if correctly executed, will not produce the results desired.

Table 8 contains metrics that are appropriate for the identification stage. Many of these are intuitive. They should not be the focus of the stage, but part of the overall process management toolkit for this stage.

Initial Screening

The second stage of the process is known as the Initial Screening stage. The input to this stage (the list of needs) should come primarily from the identification stage. Feedback from other stages is always welcome as inputs. Here the inputs from that stage are further refined. This refinement consists of explicitly describing the needs and/or requirements that a given capability or potential solution might address. This would be done using a document of some kind[25] based upon the activities of the previous stage. This document is really a draft document, as later stages of the process will refine it further. The document should, as explicitly as possible, describe the need or desired capability (Buede 1997). Information regarding potential solutions such as development cost, development schedule, and contribution to the enterprise should be listed. As this document is drafted so early in the front-end process, this information is expected to change and be adjusted. Any potential solutions to the need identified will also describe the approach used to achieve the goal (i.e. the plan). This

[25] Or any form of object or device that can communicate the required information.

information will address the technology required - what exists and what still requires development (Frohmna 1978; Smith and Reinertsen 1992; Moenaert, Demeyer et al. 1995; Khurana and Rosenthal 1998). Additional information might be a rough order of magnitude estimate on what the development costs might be. Additionally, unit cost targets may be initially estimated.

The primary activity of this stage is the collection of all of these potential solutions or ideas, understanding how they address the user need or customer requirement, and categorization into multiple categories based on perceived risk and required development (Smith and Reinertsen 1992; Bacon, Beckman et al. 1994; Leonard-Barton, Wilson et al. 1994; Rosenthal 1998). Knowledge management is very important as it captures the key information and competencies of the organization and provides a framework for its collection, organization, and dissemination throughout the organization. Additionally, the portfolio management function, providing the organization with a mixture of short, medium, and long-term solutions, must be active in this stage as it is essential for success (Cooper 1996; Cooper and Kleinschmidt 1996; Rosenau 1997; Khurana and Rosenthal 1998; Rosenthal 1998). At the end of this stage a decision is reached on which potential solutions should be pursued and those that should not go forward. This decision is based upon various criteria, such as alignment with key enterprise goals, and fit with core competencies of the organization, among others. This constitutes the preliminary screen or the 'rough look' at an idea. A decision to pursue here does not mean a product launch decision is reached and massive company or organizational resources are committed to the project. Rather, it means the committee or decision-making body feels that the idea should be further explored and at this point is a likely candidate to become a new product. A decision to proceed means the ideas and/or solutions enter the next phase of concept development (Frohmna 1978; Cooper 1997; Rosenau 1997).

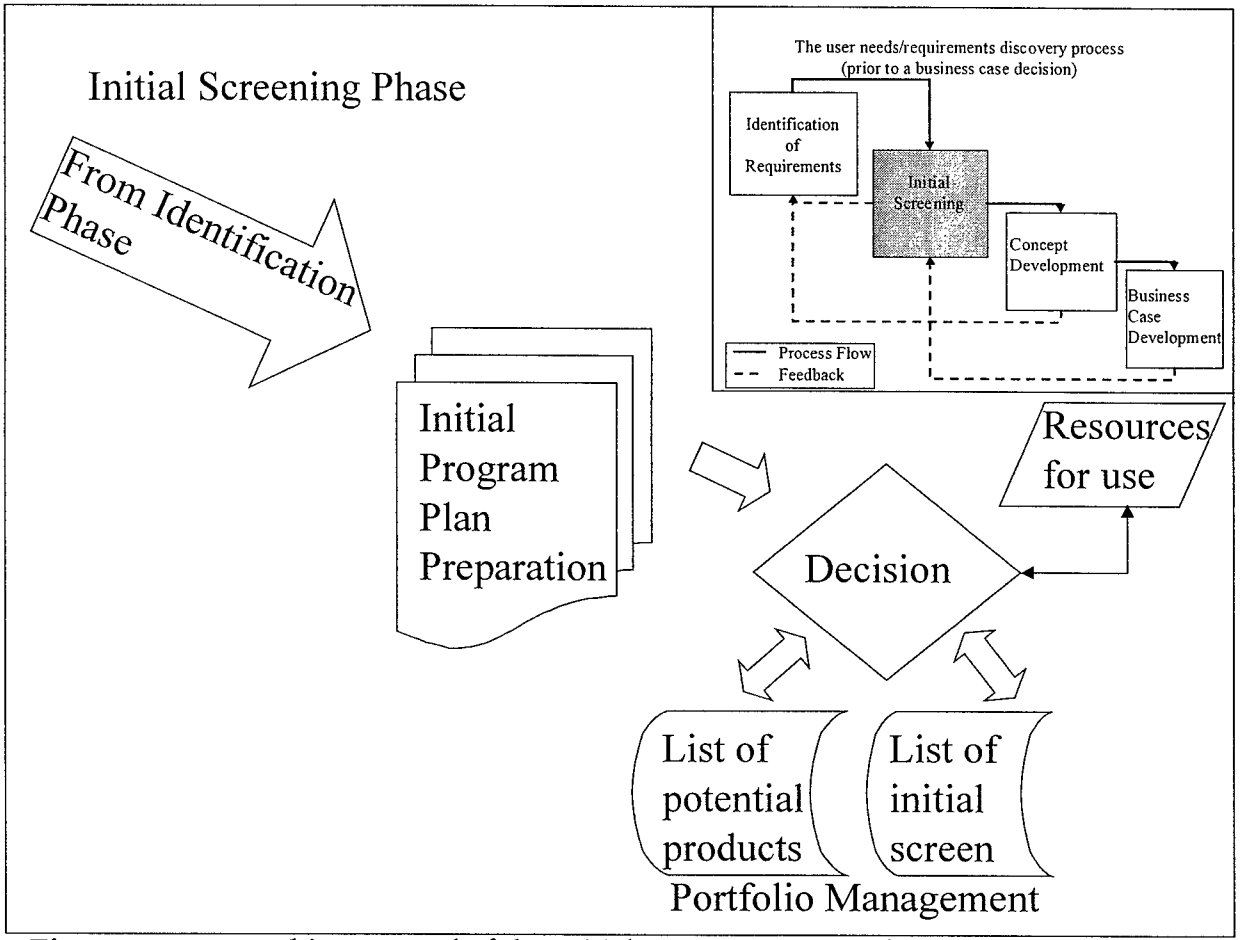


Figure 15. Graphic Portrayal of the Initial Screening Stage of the Front-end Framework

Organizationally, a centralized decision making body must be empowered to make decisions relative to these ideas (Datar, Jordan et al. 1996). Additionally, the body must also have a 'free rein' on their portion of the budget. In essence, an approval to proceed releases funds that will further develop and refine the ideas. The decision to proceed guarantees the necessary resources for both concept development of the idea and for preliminary technology development (Gupta and Wilemon 1990; Cooper 1996; Cooper and Kleinschmidt 1996). These funds are relatively small and are better known as 'seed' money for promising ideas. This money is not unlimited and strict exit criteria are required before funds are authorized or approval to enter the next phase is given.

The decision making body should be composed of senior individuals within the firm. These people likely occupy several decision making positions throughout the organization. The team needs to remain relatively small and whatever method used to reach decisions is agreeable as long as it correctly

reflects the urgency of the need or the time pressures of the market (Smith and Reinertsen 1992; Cooper 1995; Khurana and Rosenthal 1997; Tabrizi and Walleigh 1997).

A metric to measure this stage is the mix of long term vs. short-term potential projects that can be pursued. This metric also forces insight into the entire length (time required to complete; the phasing of new product market launches; etc.) of the product development process. The entire scope of downstream activities must be taken into account to judge the proper time frame for the product introduction. Additional metrics for the process could be the pass/fail rate as well as current resources expended vs. the original resource plan for the front-end. Table 8 lists some additional metrics appropriate for the screening stage. The list is not intended to be all-inclusive.

Concept Development

The third step of the process is the most familiar to most readers of Product development literature. Here, research and development is conducted into the feasibility of the idea. This step is analogous to the military's Analysis of Alternatives step. Firm answers to most unknown requirements are achieved during this phase and are clear and concise with measurable outcomes and ranges clearly indicated (Cooper and Kleinschmidt 1987; Cooper and Kleinschmidt 1993; Cooper 1994; Cooper 1995; Moenaert, Demeyer et al. 1995; Cooper and Kleinschmidt 1996; Kalyanaram and Krishnan 1997; Rosenthal 1998). These results are documented in the draft plans that accompany this project. Furthermore, these plans become the basic piece of the business case for the project.

The overall goal of this stage is to further define and explore the potential 'solution space' of the concept (Cooper 1994; Bernstein and Rebentisch 1996). As a result of these activities, the process will come up with the best mix of 'requirements' and/or key objectives to be satisfied. The individual processes used will likely mirror those used by the first stage of the process. Whereas ideas may have been based on small or cursory inputs from customers or the market, much further definition and exploration can be done. QFD, Pugh, Conjoint Analyses can be expounded upon from the first stage (Dahan 1998; Dahan 1998).

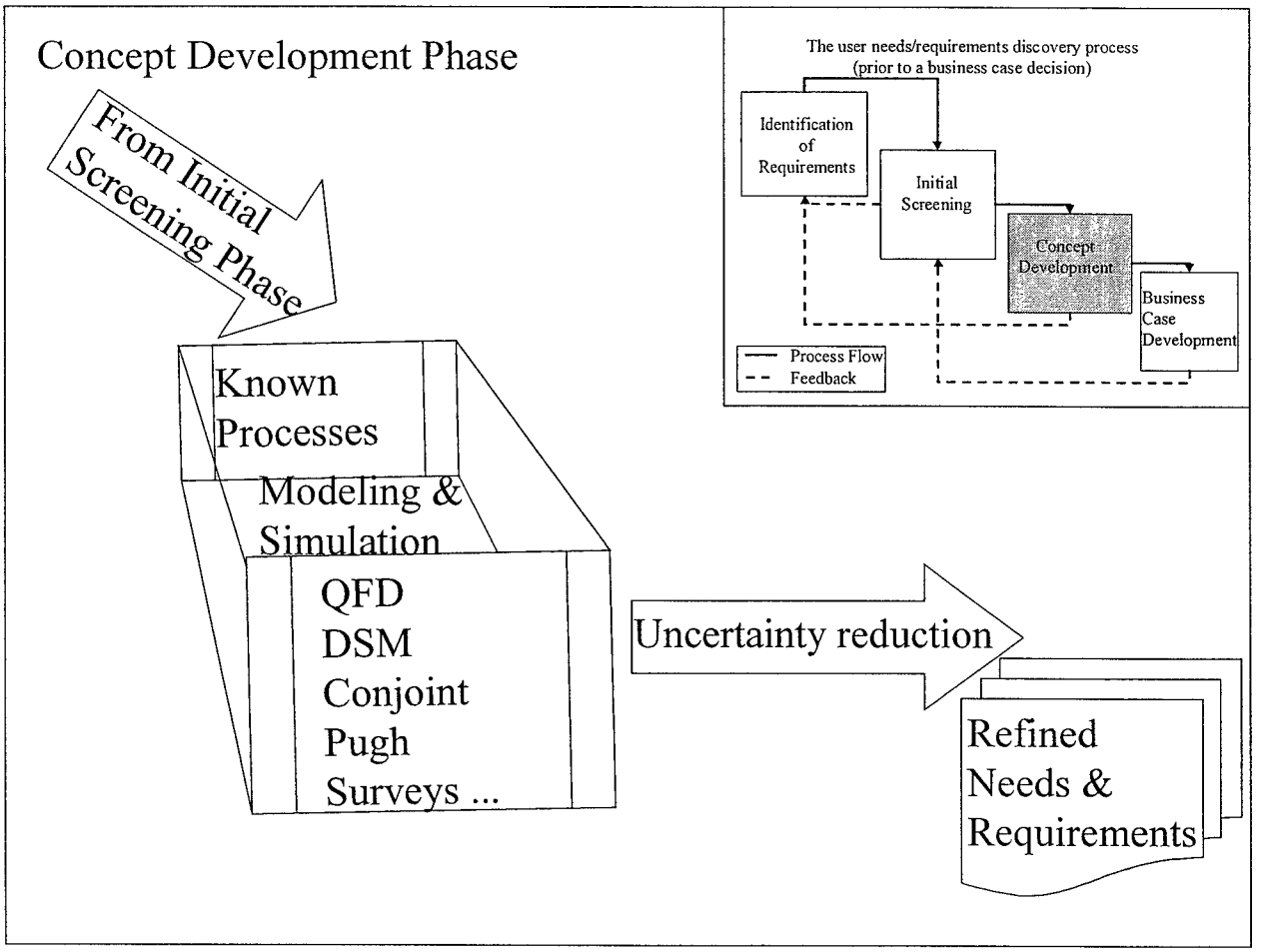


Figure 16. Graphical depiction of the Concept Development Phase

Beginning the process with these structured methods and keeping the cycle time short during the first two phases will allow the third phase to build directly upon the initial work. Requirements should be clearly specified in terms of those requirements that are absolutely necessary, those that would be desirable to have, and those that would go beyond the minimum requirement and delight the customer or end user (Bacon, Beckman et al. 1994; Cooper 1994; Cooper 1996; Huang 1999).

The overall outcome of this phase is the required information to build a business case for a product development launch decision (Cooper 1997). This required information includes the architecture of the product (whether existing or next generation), interfaces identified and possibly prototyped, extensive use of modeling and simulation; and visions of the overall customer support plan (Iansiti

1995; Ulrich and Eppinger 1995; Khurana and Rosenthal 1997; Tabrizi and Walleigh 1997; Rosenthal 1998).

Organizationally, this phase should be conducted by the same team and be given direction from the same management as the first two stages of the framework (Cooper 1995; Cooper 1996; Datar, Jordan et al. 1996; Tabrizi and Walleigh 1997). This stage very much mirrors the initial Identification of Requirements stage. However, the project has developed to the point that it has a limited budget just to explore the Requirements space of that particular idea. Furthermore, studies and analysis are encouraged to go much deeper than the initial cursory review the idea received in the Identification stage. The processes used are much the same, however, some project management skills must be employed to keep the activity focused on the outcome.

Metrics for this phase include a reduction of 'unknowns' in the draft documentation from previous phases, the cycle time of this phase in particular, as well as the overall cycle time to date (Moenaert, Demeyer et al. 1995). Table 8 lists some of these and describes their appropriate application.

Business Case Development

The last phase consists of the business case preparation and decision to launch a product or not. The overall goal of this phase is to explicitly categorize and define efforts to be pursued by the organization. The input to this phase comes directly from the previous phase. It includes all information gathered, including any reports or studies conducted about an idea or project. The process to be used during this phase is typically one of documenting the results of the previous phase in a manner that will allow the decision makers to understand the full implications of a product launch decision. The activity of documenting is really translating as much of the team's implicit or tacit knowledge into explicit knowledge.

Such information must be presented with the concept of employment of the product that corresponds to a clear and concise description of the product concept (Cooper and Kleinschmidt 1987; Cooper 1994; Cooper 1995; Cooper and Kleinschmidt 1996). The concept of employment is simply an explanation of how the product will be used, and what environments the product will operate in. Also, in addition to the information required for a business case, assuming a positive decision, enough information is required for the product development organization to take the information and get the

new product to market as quickly as possible (Cooper and Kleinschmidt 1987; Smith and Reinertsen 1992; Tabrizi and Walleigh 1997; Khurana and Rosenthal 1998). The information indicates how the product is aligned with the objectives of the company and the timeframe of impacting those objectives (Cooper 1994; Murphy and Kumar 1996).

The plan will also contain contingency plans, such as multiple product concepts, alternative technologies developed in parallel, and sometimes competing design solutions, to give the organization agility as the overall environment changes faster than the overall product development system can react (Khurana and Rosenthal 1997). The plan should also contain information how the product replacement is planned and how it forces the development of replacement products with enough time to get into the market. This information includes simple cost and benefit analysis to the organization. This information can be communicated through the plan's comparison of the architecture of the proposed product with that current organizational standard or the next generation. This comparison is explicit and goes into great detail about the similarities and/or differences to the existing architectures (Iansiti 1995; Ulrich and Eppinger 1995).

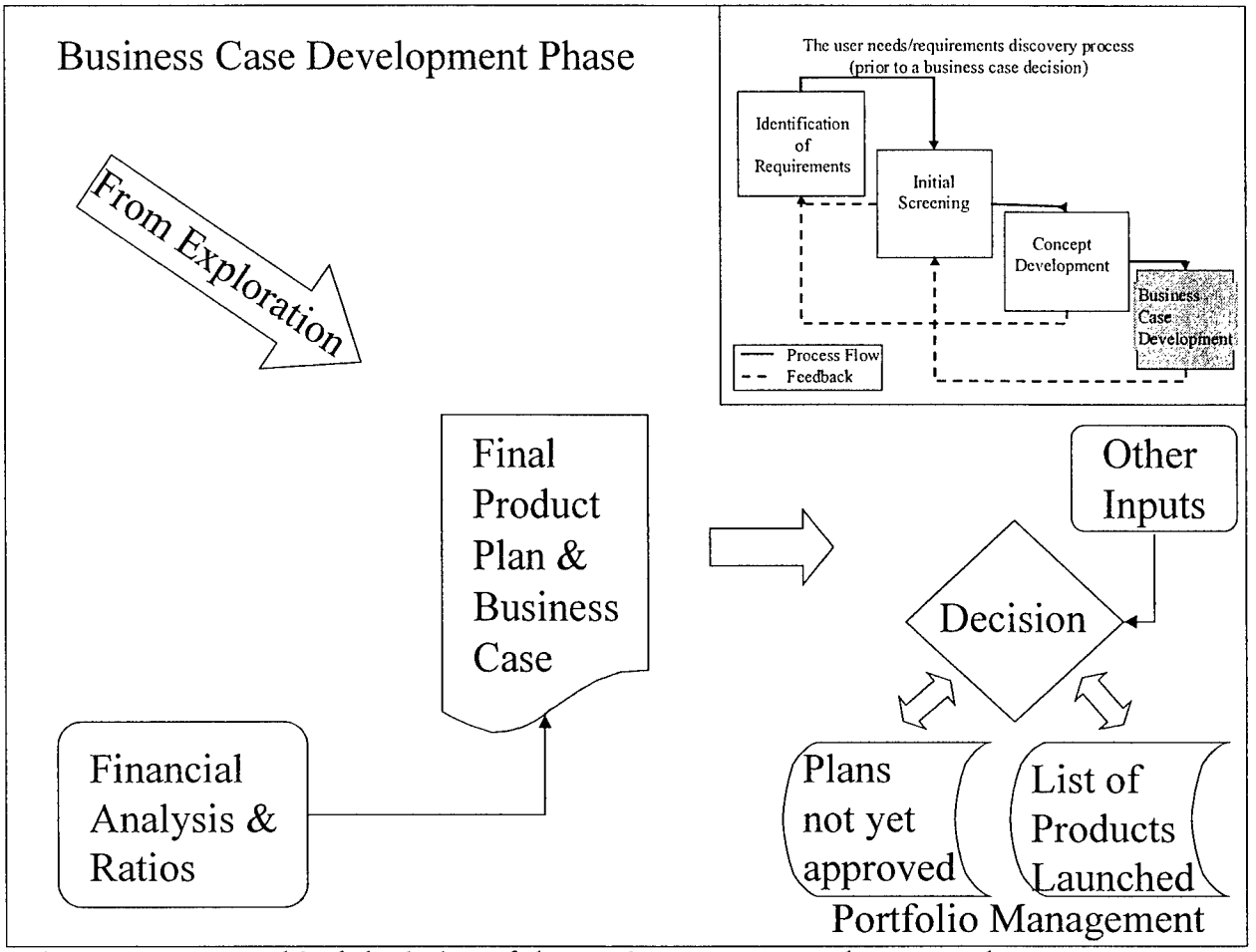


Figure 17. Graphical depiction of the Business Case Development Phase of the Front-end Framework

The final result is a decision to launch a product and the product development activities required to develop and deliver a final product. Such a decision commits the organization to not only the product's launch but also the required resources to do so (Cooper 1996; Cooper and Kleinschmidt 1996). Furthermore, this decision should be made in an environment of cross-project understanding and insight (Frohmna 1978; Cooper 1997; Khurana and Rosenthal 1997; Rosenau 1997; Khurana and Rosenthal 1998). This understanding and insight includes information about the product relationship with other ongoing development projects in terms of the values of the affected resources. The decision-makers should also take the opportunity to set the vision for the product development activities as well as any necessary decisions on technology insertion (Iansiti 1995; Khurana and Rosenthal 1997).

Organizationally, the decision making body must have the authority to commit the resources of the organization based upon the information in the business case. This decision should also mark the formal entry of the product into the product development process of the organization, whether it is a typical stage-gate process or another type of process.

Metrics for this stage include a mixture of typical business metrics as well as product and process metrics. These include the number of product features (funded vs. unfunded), Return on Investment, Net Present Value, Cycle time of the entire process, Time since the last product revision, time since the last revision of the product vision (typically no more than two years).

Process Enablers

It is appropriate to begin a discussion about the enablers of the process. They have been alluded to throughout this section. Now they will be discussed in depth. Some of these enablers operate across or span the entire process and it is not appropriate to try and partition them into one of the four process steps. Others are very specific to certain steps and will be treated accordingly.

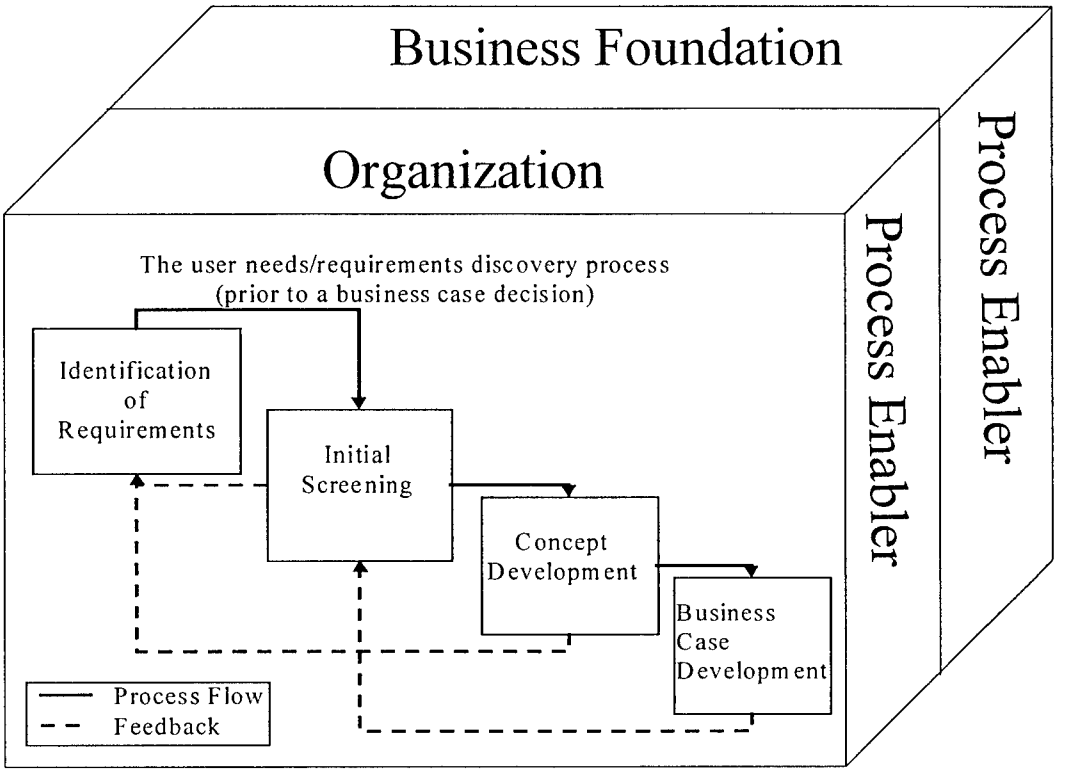


Figure 18. Graphical Depiction of the Relationship between the Front-end Framework and the Process Enablers

Organizational Enablers

This section will describe the 'to be' (or Best Practices) desired state of the product development organization. The overall focus of the organization's people is on understanding user needs. The goals and strategy of the organization are known and understood by all employees and is explicit for the front-end of product development (Cooper 1996; Cooper and Kleinschmidt 1996). They understand how their specific job relates to achieving those goals.

The organization is structured to automatically generate cross-functional inputs (Cooper 1994; Cooper and Kleinschmidt 1996). This is done through the use of small teams, such as Integrated Product Teams whose members represent various backgrounds (Smith and Reinertsen 1992), allowing these teams to negotiate their roles and responsibilities prior to beginning the front-end process (Khurana and Rosenthal 1997; Tabrizi and Walleigh 1997), and encouraging teams to form on a self-selecting,

spontaneous basis (Gupta and Wilemon 1990; Cooper and Kleinschmidt 1995; Cooper and Kleinschmidt 1996). Rather than restrict employee participation in the front-end, it should be encouraged and not restricted when actively engaged on a project for the front-end (Smith and Reinertsen 1992; Cooper and Kleinschmidt 1996; Khurana and Rosenthal 1997). Finally, the team should remain intact for the entire front-end process and leadership of the team should be placed in senior individuals who have done well in technical and managerial skill evaluations (Cooper and Kleinschmidt 1987; Smith and Reinertsen 1992; Cooper 1994; Cooper 1994; Leonard-Barton, Wilson et al. 1994; Cooper 1995; Cooper and Kleinschmidt 1996; Tabrizi and Walleigh 1997). The team consists of a small 'core' group that can draw upon a larger periphery of other teams/functional groups.

Business Foundation Enablers

An absolute requirement for the business environment of the organization is the establishment, measurement and adherence to a formal front-end process (Cooper and Kleinschmidt 1987; Cooper 1994; Cooper 1996; Cooper and Kleinschmidt 1996). One organization should be responsible for the front-end of product development (Cooper 1996; Datar, Jordan et al. 1996). There is a distinct lack of organizational layers between management and the front-end process. Ideally, the same organization that does the front-end of product development also controls the entire product development process (Khurana and Rosenthal 1998) (Khurana and Rosenthal 1997).

Executive Reviews are done, but management plays a different role than accustomed to, that of coach and advisor, not decision-maker (until the screening and business case decisions have to be made – then they are accountable). The reviews are conducted to give insight, not necessarily direction (Smith and Reinertsen 1992; Cooper and Kleinschmidt 1996; Karlsson and Aehstroem 1996; Buckler 1997; Khurana and Rosenthal 1998). Built-in 'triggers' force decisions to be made before proceeding with further development. These triggers allow management to resume its familiar role of decision making. The 'triggers' in the framework are found at the initial screening stage and also the business case decision. Application of this concept should be extended well into the typical phase gate product development system of the organization (Frohmna 1978).

Once started, programs are ensured stability in schedule and money. This requires dedication on the part of the business, as well as an understanding of the importance of the investment decisions (and

ties directly into the people and organizational enablers previously discussed) (Tabrizi and Walleigh 1997). Portfolio management must take into consideration the balance between resource capacity and process flexibility. This includes understanding the relationship between project development speed and resource starving projects, as well as the relationships between short-term and longer-term projects (Leonard-Barton, Wilson et al. 1994; Khurana and Rosenthal 1997; Rosenau 1997).

Programs require complete and explicit definitions (i.e. good requirements). In this way, programs avoid unnecessary changes and enjoy stability in their plans and strategy (Khurana and Rosenthal 1998). This includes tightly coupling the efforts of the R&D organization with the current product concepts within the front-end (Cooper and Kleinschmidt 1996). A common database or requirements management tool is essential to fostering communication from one stage to the next, and ultimately into the full-blown product development process (Gupta and Wilemon 1990; Khurana and Rosenthal 1997).

Technical competency of the workforce is essential to success. A Robust training program in functional depth and organizational breadth is required to keep people in the front-end of new product development aware of and knowledgeable of new technology, techniques, and processes applicable to new product development (e.g. market research) (Cooper and Kleinschmidt 1987; Cooper 1996).

Core competencies are identified and strengthened by the organization's management. Although the methods to identify and strengthen these competencies are varied, the core competencies should embody the essence of the organization: the activities, capabilities, and resources that are either unique to the organization or are key to the success and well being of the organization. Management vision and involvement built upon these competencies, are well articulated, and communicated to all employees.

Process Metrics

The following table indicates those metrics that apply to the different stages of the framework and also the enabling practices. Those metrics that apply to each stage are considered to be key metrics that are to be used to assess the overall condition of the front-end process.

Table 8. Front-end Process Metrics

Metric (units of measure)	Application to Framework*						Desired trend	Frequency of Update
	S1	S2	S3	S4	O	B		
Cycle time (time – days, weeks, months – as appropriate)	■	■	■	■		■	Downward	Continuous
Customer satisfaction (scale measure)	■	■	■	■	■	■	Upward	Monthly, or less frequent
Invention rate (# of patents, copyrights, etc.)	■	■	■	■	■	■	Steady or constant	Continuous
Time required to find necessary information/data (time – days, weeks, months – as appropriate)	■	■	■	■	■	■	Downward	Each phase
Time required to access necessary data/information (time – days, weeks, months – as appropriate)	■	■	■	■	■	■	Downward	Each phase
Staff stability (ratio)	■	■	■	■	■	■	Steady or constant	Each phase
Number and length of supplier relationships over time (number & time – days, weeks, months – as appropriate)	■	■	■	■	■	■	Steady or constant	Each phase
Seniority of Team (years, experience)					■	■	Steady or constant at an agreed upon level (i.e. 3 years with high standard deviation – implies experienced leadership and also young employees being trained)	Each phase
Portfolio mix (Mix of solutions into near, mid, and far		■		■		■	Steady or constant	Monthly

categories)								
Cycle time of product releases (time – days, weeks, months – as appropriate)				■		■	Steady or constant	Yearly
Percent commonality across different products (percentage)				■		■	Upward	Yearly
Return on Investment (value in units of currency)		■		■		■	Steady or constant	Each project
Net Present Value (in units of currency)		■		■		■	Steady or constant	Each project
Lifecycle costs (in units of currency)		■		■		■	Steady or constant	Each phase
'Successful' projects vs. failures (ratio)				■		■	Steady or constant	Each project
Number of rework cycles/feedback (a number)	■	■	■	■	■	■	Downward	Yearly
Number of outstanding product features vs. those built (A ratio)				■		■	Steady or constant	Each project
Time elapsed since product vision updated (time elapsed)				■		■	Steady or constant	Yearly
Ratio of Obligations to Budget (ratio)		■		■		■		
Stream rate (# of ideas vs. time – days, weeks, months – as appropriate)	■					■	Steady or constant	Monthly

* S1 = Identification of Requirements Phase, S2 = Initial Screening Phase, S3 = Concept Development Phase, S4 = Business Case Development Phase, O = Organizational Enablers, B = Business Foundation Enablers

Understanding the relationships among these metrics can lead to leveraged advantages. For instance, many of the business process enablers are also prevalent in the screening stage and in the business case decision stage. These metrics are understandably more 'business' and business decision oriented. The key understanding is that these typical business metrics apply only to those two portions of the framework, and specifically to the potential projects under evaluation. Other metrics should be used to assess the 'health' of the other stages of the front-end process.

Best Practices Spectrum/Maturity Matrix

The following tables present the spectrum of process activity found within New Product Development. These tables will allow organizations to evaluate the 'maturity' of their own processes vs. an ideal front-end of product development. Graphical depictions of the same information will also very quickly convey a sense of an organization's process relative to other organizations.

The matrix has a spectrum of performance. An organization that finds its process practices are best described by the definition given in Level 1 have a Least Mature Process. Alternatively, an organization that is best described by those definitions given in Level 4 have a process that is Most Mature. It is possible for an organization to not identify with any definition at all. In these cases, there is likely no process at all in place or the process is in an emergent state. Also organizations may have multiple practices that span a range of levels. This is expected. Every organization's process is in a different state of maturity and the path of improvement for each organization's process is different.

The level definitions were developed by closely examining the practices identified in the literature and extrapolating degrees of 'goodness' that reflect how much a particular practice or concept has been implemented in an organization's front-end process. This information was used to create the different descriptions for each level. Ensuring that the differences reflected in the descriptions for each level were measurable and not just open to interpretation, the matrix was populated. Additionally, the element descriptions were iterated during data collection and analysis, helping to ground the framework in empirical observations. The maturity matrix is not intended to be all-inclusive or complete. As additional Best Practices emerge and are found, they can be placed within the matrices at the most appropriate locations.

Table 9. Maturity Matrix for the Identification of Requirements Stage

Element Number	Level 1	Level 2	Level 3	Level 4
1.1	Customer needs are derived based upon previous industry experience, Subject Matter Experts, and sales / marketing feedback. Little or no market research or analysis is done.	At least one structured method is used to elicit and gather customer needs, using the voice of the customer. Here, some market research or analysis is done.	Multiple structured methods are used to elicit and gather customer needs. Done with substantial market research and analysis.	Multiple structured methods are used to elicit and gather needs for the different stakeholders / customers. Relates to extensive market research and analysis.
1.2	Requirements are stated in terms that reflect the capabilities or understanding of the organization and are achieved only through one or two specific applications.	Requirements are specified in terms of a specific type of solution envisioned by the customer through market research.	Requirements are specified to encourage creativity in the 'space' defined by the voice of the customer and market research data.	Requirements are specified to describe a desired end-state, or a capability desired.
1.3	Structured methods 'validate' preconceived solutions.	Structured methods determine potential solutions by 'variations on requirements'.	Structured methods used to explore 'trade space' allowed by requirements to determine potential solutions.	Structured methods used to develop required capabilities or end-states into potential solutions.

Table 10. Maturity Matrix for the Screening Stage

Element Number	Level 1	Level 2	Level 3	Level 4
2.1	Development projects (potential solutions) are not managed by portfolio, rather by managerial fiat.	The portfolio of development projects (potential solutions) is split among multiple groups / organizations. There is no mention of required technology development.	The portfolio of development projects (potential solutions) lists required technology development. The portfolio is shared between groups / organizations.	The portfolio of development projects (potential solutions) plans for required technology development. The portfolio is controlled by one group / organization.
2.2	Risk does not play a large factor in decisions to proceed with further development. Potential return is considered.	Approval to proceed into further development is granted to development project although some risks and potential returns are based largely on promise.	Development project risk and potential return must meet generic, predetermined standards before approval to pursue further development.	Development project risk and potential return must satisfy pre-negotiated criteria before approval to pursue further development.
2.3	Decision for further development does not include guaranteed resources. Resources are controlled by multiple organizations. Little or no resources are available for development projects.	Decision for further development does not guarantee resources. Resources are controlled by a different organization(s).	Decision for further development guarantees resources. Resources come from different organizations.	Decision for further development guarantees resources. Resources are dispersed at the discretion of the portfolio management.
2.4	Required technology research and development is not explicitly tied to approval for further development. Resources are controlled by	Required technology research and development may proceed upon approval for further development. However, resources are not guaranteed.	Required technology research and development is given necessary resources upon approval for further development. Resources	Required technology research and development is given necessary resources upon approval for further development. Portfolio

	multiple organizations. There are little or no available resources for these activities.	They are controlled by different organization(s).	come from different organizations.	management controls resources.

Concept Development

Table 11. Maturity Matrix for the Concept Development Stage

Element Number	Level 1	Level 2	Level 3	Level 4
3.1	Product requirements are listed.	Clear and concise product requirements. May be difficult to measure or test.	Clear and concise product requirements with measurable outcomes and acceptable ranges on most requirements.	Clear and concise product requirements with measurable outcomes and acceptable ranges on all requirements.
3.2	No trade-off analyses performed. Requirements are generated in an ad hoc manner.	Trade-off analysis done on given requirements.	Trade-off analysis on multiple requirements mixes.	Trade-off analysis on multiple requirements mix and 'sets' of solutions.
3.3	Product features are not prioritized. Everything has equal importance.	Product features are prioritized into 'must have' and 'like to have' categories.	Product features are prioritized within 'must have' and 'like to have' categories.	All product features are prioritized. Additional information to 'delight' the customer is also included.
3.4	No architecture is specified.	The architecture is evolving.	The architecture of the solution is clear and precise.	The architecture of the solution is clear and precise. It embraces open standards and future growth where appropriate.
3.5	This step conducted by	This step conducted by	This step conducted by	This step conducted by front-

	organization supplying resources.	organization supplying resources; consultation by front-end process group is optional.	organization supplying resources; consulted by front-end process group.	end process group.
3.6	Service / support/ maintenance concepts are not required to be addressed in this stage.	Service / support/ maintenance concepts receive little mention in concept.	Service / support / maintenance concepts must be explicitly described. Estimated costs are not required.	Service / support / maintenance concepts must be explicitly described to include estimated costs over the lifetime of the solutions.
3.7	No prototyping done.	Prototyping done sporadically; usually along only one dimension of interest.	Prototyping usually done. Key interfaces are prototyped.	Appropriate prototypes along dimensional axes of 'physical-analytical' and 'comprehensive-specific' are used; developed according to defined methodology (Ulrich and Eppinger).

Business Case Development

Table 12. Maturity Matrix for the Business Case Development Stage

Element Number	Level 1	Level 2	Level 3	Level 4
4.1	Approval of concept denotes permission for funding to be sought. There is no guarantee the concept will be developed.	Approval of concept commits organization to launch of product. Resources must be located from a sponsoring entity in the organization.	Approval of concept commits organization to launch of product as soon as resources are available.	Approval of concept commits organization to launch of product and commits resources of organization.
4.2	Description of the Product Concept exists.	Description of the Product Concept exists, but addresses	Description of the Product Concept exists, and includes a	Description of the Product Concept exists; is clear,

		only employment/operational issues.	comprehensive concept of operational employment.	precise, and concise; and is integrated with the concept of operational employment.
4.3	The business plan contains no mention of the corporate strategy.	The business plan references the corporate strategy.	The business plan is tailored to corporate strategy but does not include any specific information how the product does so.	The business plan contains detailed information how the product will contribute to the objectives of the corporate strategy, including specific information of how much, when, and for how long
4.4	No product replacement strategy exists.	A product replacement strategy is outlined, but contains no specific information.	The product replacement strategy is explained with information regarding the costs and benefits to the organization.	The product replacement strategy is outlined with specific information regarding the costs and benefits to the organization with a timeline giving the necessary predevelopment work that must occur for a successful transition.
4.5	There is no mention of technology planning, maturation and insertion in plan.	Both technology planning, maturation and insertion are acknowledged to occur, but the plan only addresses its insertion.	Technology planning, maturation and insertion is discussed in detail but lacks information on how it will be accommodated.	Technology planning, maturation and insertion are outlined in detail along with defined process(es) that will be used for each to occur.
4.6	Architecture of concept is not considered.	Architecture of concept is not clear.	Architecture of concept mentions the architecture of the existing company products or the 'next' generation of products, but does not detail	Architecture of concept is explicit in its relationship to the architecture of the existing company products or the 'next' generation of products.

			its relationship to them.	
4.7	Contingency planning is not done during development of the plan.	<blank>	<blank>	Contingency planning a regular business activity.
4.8	No linkages to other projects are noted or identified.	Relationships to other development projects noted.	<blank>	Relationships to other development projects are explained by including information that indicates the value of the relationships in terms of all affected resources.

Organizational Enablers

Table 13. Maturity Matrix of Organizational Enablers for the Front-end Process

Element Number	Level 1	Level 2	Level 3	Level 4
5.1	The organization has no communicated strategy for the front-end of product development.	The organization has implicit guidance for the front-end of product development.	The organization's product development strategy is explicit for the front-end but has no general measures of performance.	The organization's product development strategy is explicit for the front-end and contains specific measures that drive the behavior of the front-end.
5.2	The organization does not use cross-functional inputs.	The organization encourages but does not solicit cross-functional inputs.	The organization solicits cross-functional inputs.	The organization is structured to automatically generate cross-functional inputs.
5.3	The preferred organizational structure is functional in nature.	The preferred organizational structure is a functional matrix organization.	The preferred organizational structure is an Integrated Product Team with less than	The Integrated Product Team consists of a small 'core' group with less than 10 members.

			25 members.	
5.4	Roles and responsibilities for the preferred organizational structure are rigid and strictly enforced. The organization seeks to protect its traditional roles and responsibilities in the front-end process.	Roles and responsibilities for the organization in the front-end process evolve over time.	Clear roles and responsibilities for the organization are established in advance of the front-end process.	Clear roles and responsibilities for the preferred organizational structure are negotiated as part of the front-end process.
5.5	No method in place to assign projects to employees. Done in an ad hoc fashion.	Participation on project based on perceptions of project complexity and importance.	Participation based upon skills and knowledge evaluations in relation to the project area.	The preferred organizational structure relies on self-selected and self-directed teams.
5.6	No provisions to keep team intact for the duration of the front-end process.	Provisions to keep some team members intact for the duration of the front-end process exist and are used.	Provisions for team stability for the duration of the front-end process are used and a product champion exists.	Entire team remains intact for the duration of the front-end process.
5.7	Leadership of development efforts is assigned in an ad hoc fashion.	Leadership of development efforts depends upon organizational perceptions of importance.	Leadership of development efforts determined solely on seniority at workplace.	Leadership of development efforts given to senior employees based upon technical & managerial skill evaluations.
5.8	Employee participation in development efforts follows a set time allocation.	Employee participation in development efforts follows a set time allocation but is negotiable if demands require.	<blank>	Employee participation in development effort is not restricted.

Table 14. Maturity Matrix of Business Enablers for the Front-end Process

Element Number	Level 1	Level 2	Level 3	Level 4
6.1	A process to identify needs and requirements has not been formally defined.	A formal process exists. There are no measures in place.	A formal process exists. Measures track process performance, but they are not consistently followed.	A formal process exists and is consistently followed and measured.
6.2	There is no Management involvement in the front-end process. Management acts as a judge/gatekeeper to the front end and remains distant to the front-end process.	Management receives regular briefings and other status reports about the activities in the front-end process.	<blank>	Management has active interaction with the front-end in a coaching and/or advisory role. There is a distinct lack of organizational layers between management and the front-end process.
6.3	Employee training is done at the discretion of the employee.	Employee training is mandatory. All employees receive the same training regardless of job position or function.	Employee training is mandatory at a specified number of hours each year. Common training is done with optional training available. Offerings are limited for training related to job activities.	Employee training is required in the specialty of each employee. Other training in areas of interest that may not be related to specialty of each employee is given in a 'holistic' fashion giving the employee an opportunity to understand the different functional areas of the company. Training is directed towards continuous improvement.
6.4	The organization does not use portfolio management of any	Portfolio management is conducted only after the	Portfolio management based solely upon returns to	Understanding resource capacity vs. flexibility in front-

	kind.	business case is determined.	organization.	end considered in portfolio management. Tradeoffs between resource-starving projects and development speed are understood. The relationships between short-term and longer-term development projects are key to management decisions.
6.5	No one organization is responsible for the front-end process. All cases are ad hoc.	One organization traditionally leads the first stages of the front-end process, and then another organization takes over.	One organization takes the lead for the entire front-end process and is supported by other organizations in that role.	One organization shepherds ideas from the beginning of the front-end process until product launch.
6.6	Multiple databases and tools are employed to assist process participants complete their jobs. The tools do not share information between them.	Multiple linked databases and tools are employed to assist process participants complete their jobs. Information sharing between the tools is possible.	A common database or IT tool exists to help process participants complete their jobs. Most if not all members of the organization use this tool.	A common database or IT tool is used by all process participants in the organization. It also contains decision assistance methodologies based upon predetermined criteria.
6.7	R&D develops its own plans and areas of focus without consulting product development efforts.	R&D projects seek sponsors within the product development front-end	R&D projects and product development efforts collaborate together on an as needed basis.	R&D is tightly coupled with the current product concepts in the front-end.

CHAPTER 4 - RESEARCH DESIGN

This chapter discusses the approach of the research, the key questions to be answered, how the research will be performed, and explains the primary deliverables. Additionally, a discussion about research validity and the population and sample of the research will be given.

Population and sample

The sample population group of this study includes the major Air Force Commands as well as other Air Force officials at the Pentagon[26]. Among the other services, those branches that deal primarily with developing requirements for aerospace vehicles are also considered, although other areas of these services will be examined for additional insight. Therefore, the samples from the military include each of the services, and four Unified Commands, for a total of eight military organizations.

The samples from industry include chemical application companies, commercial airline companies, other aerospace companies, and computer industry companies for a total of 8 companies. These companies were specifically chosen for a variety of reasons. Two of the companies were specifically recommended for study by consultants who have done front-end evaluations and indicated that these were among the most advanced. The computer companies were included in the sample because of the rapid cycle times of new technology and product obsolescence, which the US Military faces as a constant threat as well. The Airlines were included because they represented end user organizations similar to the Military's Unified Commands and they both need and must use highly complex, technical products to do their jobs. Finally, several aerospace companies were included because they are in the same domain space as the US Air Force, and are typically similar to the US Air Force in dealing with highly expensive, very complex product development issues.

One more sample, a foreign military, is included. This military organization was included in the sample because of the different way it approaches product development; it is in many respects a hybrid of the commercial and military organizations.

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[26] Depending upon the commercial aerospace company chosen, another AF command may be chosen for study for better alignment across business markets/areas.

Study Design

The preferred method of study was the case study. There were multiple case studies to ensure the general applicability of this work. This work relied upon purposive sampling in data gathering and building of the cases. The case study method was more appropriate as most of the questions asked in this research were of the 'how' and 'why' variety. This topic could also not be manipulated in events to meet experimental criteria.

The primary source of data was from the US Air Force as well as other field research in both the military and commercial arenas. The key questions helped bring 'Best Practices' to light, wherever they were, and helped assess the idea that a systematic process is superior to an ad hoc one.

Mapping the existing needs/requirements generation process was accomplished through an extensive review of the literature and also interviews of key players within the system. This approach was used for all of the services and commercial industry examples.

Similarly, through interviews, personal communication with key players and existing literature, data was collected that serves to give a qualitative look at the effectiveness of their processes. These were compared to the existing theory and the results were also characterized.

An idealized front-end process was developed and then using these case studies, the organizations were compared against this idealized front-end. The idealized process came from the literature, but was also validated in some sense by the field observations. As the idealized front-end process describes practices for the front-end, these practices were then translated into concise policy initiatives, that when undertaken, should yield results similar to those described in the literature and other research. The degree of implementation of the practices advocated in the process maturity matrix characterizes the organization's "leanness" of its fuzzy-front end activities[27].

Methods

The main method of research used to collect the data was the personal interview. Three other sources of information included documentation (prepared briefings and presentations as well as other documents, such as Military Regulations and Instructions and company plans), direct observation and

[27] Lean meaning the right things, at the right time and place, in accordance with the Lean Enterprise Model and other Lean Material.

participant observation (through the author's participation on the HAF 2002 Requirements Reengineering Team).

Over 325 people were interviewed, of which nearly 300 were specifically done as part of the HAF 2002 Requirements Reengineering effort. The author did not interview all of these people (only about 50 personally for the HAF 2002 effort), but the materiel gathered (notes, papers, briefings) from all of the interviews by HAF 2002 matched the requirements of this work. As a member of the core team for the HAF 2002 Requirements Reengineering effort, the author had access to a tremendous amount of data for this thesis. The vast majority of those interviewed by the HAF 2002 effort were employed in positions relating to the US Air Force or the different US Military services. About 1/3 of those interviewed held high positions of authority in their respective companies or organizations (e.g. a three-star general or vice president position) in addition to the many lower level personnel who were interviewed. For the purposes of the US Air Force Case, interviews were conducted at every Major Command that generates requirements. Additionally, interviews were conducted with Air Force Organizations that either reviewed requirements documents or approved them. Finally, interviews were conducted with individuals within the US Air Force Acquisition community that were the end users of these documents. Therefore, the case study done on the US Air Force is much more comprehensive than the other case studies.

The interviews conducted by the HAF 2002 effort were conducted to specifically assess the current state of the existing Requirements Process in the interviewee's respective organizations. All of the interviews, including those done specifically for this effort, were structured to gather as much information as possible about each organization's front-end process. Available documentation of any kind was used to further determine the organization's front-end process. Callbacks and additional visits were used where not enough information was gathered.

Upon receiving the information for each organization's process, the author began the process of organizing and categorizing the information. This information was primarily used to write each organization's case study. The case studies were made available to the companies for review to ensure accuracy of the noted observations. Most suggestions offered by these companies were not substantially substance oriented, but focused more upon clarification of process activities.

During the course of preparing the case studies, the author also scored the organizations against the process maturity matrix. To maintain a sound approach to the scoring, each element of the matrix was assigned a score of one, two, three, or four points respectively, depending upon which level of the matrix the element was in. This method was chosen to give the author the flexibility to score elements in each matrix differently to reflect the various and different practices found within each organization. For instance, a company could have a very good practice (Level 4) and an equally poor practice (Level 1) existing in the same phase of the front-end. In this case, if the phase had only two elements, the overall score for that phase for that organization would be 2.5 (4 plus 1 equals 5, divided by the number of elements in the matrix (in this case, two)). The current maturity matrix contains 37 elements, separated into six different categories, reflecting the four process phases and the two process enabling factors, Organizational and Business Enablers.

At the outcome of this scoring exercise, the resulting data was sorted and ranked. The outcome showed that commercial companies consistently outperformed the military organizations. This was of no surprise as it reflected the field observations of all of the organizations in this study.

Upon completing the writing of the case studies, the entire scoring process was redone. This was done for two reasons. The first reason was to ensure that any information that was not available prior to finishing the case study write-ups could be included in the matrix scoring. The second reason was to make sure that all of the data was scored at the same time, under the same conditions, in order to minimize any other environmental effect. The results of this scoring largely mirrored the first round of scoring, although there were a few changes reflected in the outcomes, usually in an organization moving up or down by one or two places in the matrix rankings.

After receiving feedback from the companies on their case studies, the process was scored again from scratch, for the same reasons as the second round of scoring. The outcomes of this round substianted the second scoring round. A few adjustments were made to the process matrix, in the form of clarifications and internal validity, that would make it easier for the general reader to interpret the matrix the same way as the author. Those matrix elements that were affected were rescored to ensure the results were reasonable to the element description. These few adjustments and the last overall scoring round constitued the final scoring. Upon review, the final scoring outcomes were stable in

comparison with the previous efforts. This information forms the basis of the data analysis and discussion presented in chapter 7.

The method of scoring described above ensures the represented data is valid, particularly due to the process method and the safeguards in place. Additional reasons for the validity of the data stem from the fact that similar organizations (e.g airlines, the Unified Commands, the Services, etc.) received similar scores independent of any a priori comparison. The final reason for lending validity to the outcomes presented in the data analysis and discussion chapter stems from two independent reports published by two different consulting companies. The reports produced by those companies contain some of the same organizations evaluated in this report (both military and commercial), and their report conclusions are similar to those (for the organizations common between the reports) presented in this work. The top firms reported by these studies were the top performers in the maturity matrix and there is a correlation of outcomes between these studies and this work, even though the methods used to determine the outcomes were different (i.e. this work's maturity matrix vs. entirely different frameworks in the two studies).

Other research alternatives considered

Among the qualitative research variations available, a survey was considered but was not chosen because it was not clear exactly to whom the survey should be targeted or who the players in the front-end process actually are. It was only during the interview process that contacts were made with the individuals to whom this research was most suited. Furthermore, the nature of this research demanded access to policy-making individuals and those with either process ownership or deep understanding. At the time of this undertaking, access to these individuals was impossible to secure. Through the participation on the Headquarters Air Force 2002 Reengineering Team, access to these individuals was cleared (both within the military and also from commercial organizations, who were more attentive to an effort by the Headquarters Air Force). Finally, the overall process of requirements generation is currently the subject of much attention and it was not clear what information would be or should be collected: historical, current, or data concerning a newer system being contemplated.

Concerns about Research Validity

While the research design determines the validity of the results, there are issues that may effect the applicability of the research. Because of the volatility in the system at this time, any changes made to the system could affect the applicability of the results. This is known as the 'history effect'. This appears to be the single-most serious threat to the applicability of this research.

Of course, every effort was made to avoid some of the more common threats to the validity of this kind of research. These threats apply to the principal methods employed in the research. These include poor methodology, lack of generalizability, and meandering write-ups. Frequent interaction with the thesis advisor, along with multiple peer reviews of the research, contributed to ensuring valid research design.

An additional concern existed due to the participation of the author on an Air Force team charged to 'reinvent' the Requirements Process. The author could have become too 'involved' in the outcome of the effort and bias the results of the research. However, the implications of a synergistic relationship between the purposes of this team and this research were compelling. This relationship allowed this research to build upon the work of this team, as long as the methods employed withstood the scrutiny of academia (rigor, internal and external validity, etc.). One safeguard in place was the use of a database of all related activities and existing literature. Documentation was gathered through interviews, direct and participant observation, and using source material, which was used to establish a 'causal chain of evidence' for the case studies. Explanation-building continued to build causal chains of evidence and was used to test hypotheses. Additional safeguards included the close supervision of this work by the thesis advisor. A final barrier to assimilation existed in the geographic separation between the author and the rest of the Air Force team (located in the Washington DC area).

The individual cases are addressed in individual sections of this work and a chapter or two following will contain cross-case comparisons and analysis. The analysis was done using Microsoft Excel and its Statistics Add-in. Additional statistical support was provided by a demo version of Vizlon, and a demo version of Analyse-It, both Excel software add-ins.

CHAPTER 5 - THE US AIR FORCE FRONT-END PROCESS CASE STUDY

The US Air Force has a decentralized process for its front-end. Nevertheless, it remains a formalized process. This case study will reflect both of these observations. It is also important to note that during the period of observation, major changes to the front-end processes were being contemplated. A team has been working beginning April 1999 to 'reengineer the Requirements Process' for the Air Force.

The DoD view of the Requirements Generation System was presented in Chapter 2. The Air Force has split this process into two systems, the Modernization Planning Process (MPP) and the Requirements Generation System (RGS). The MPP controls the Mission Area Analysis and the Mission Need Analysis portions as a part of the Air Force Planning process within the Planning, Programming and Budgeting System (PPBS). The RGS contains the rest of the process. The Acquisition System[28] exerts primary control over the product development process when the Milestone Decision Authority (MDA) makes a decision (Milestone I) about the product when an Operational Requirements Document (ORD) is validated and approved and also the required funding is in place.

The following diagram illustrates the overall information flow of the Air Force's front-end. An Operational Requirements Document (ORD) repeats the process beginning with the Requirements Organization.

[28] See Appendix F for more information about the specific nuances of the Air Force application of the PPBS.

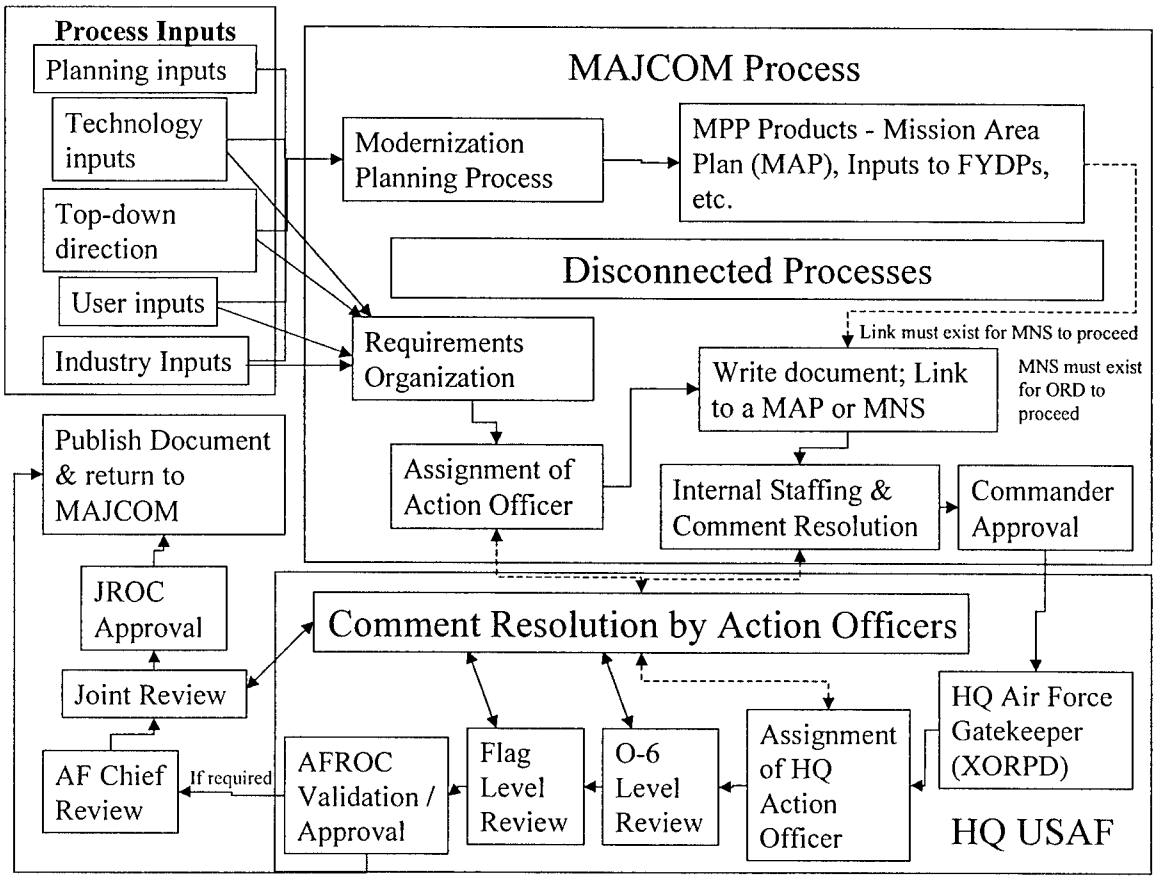
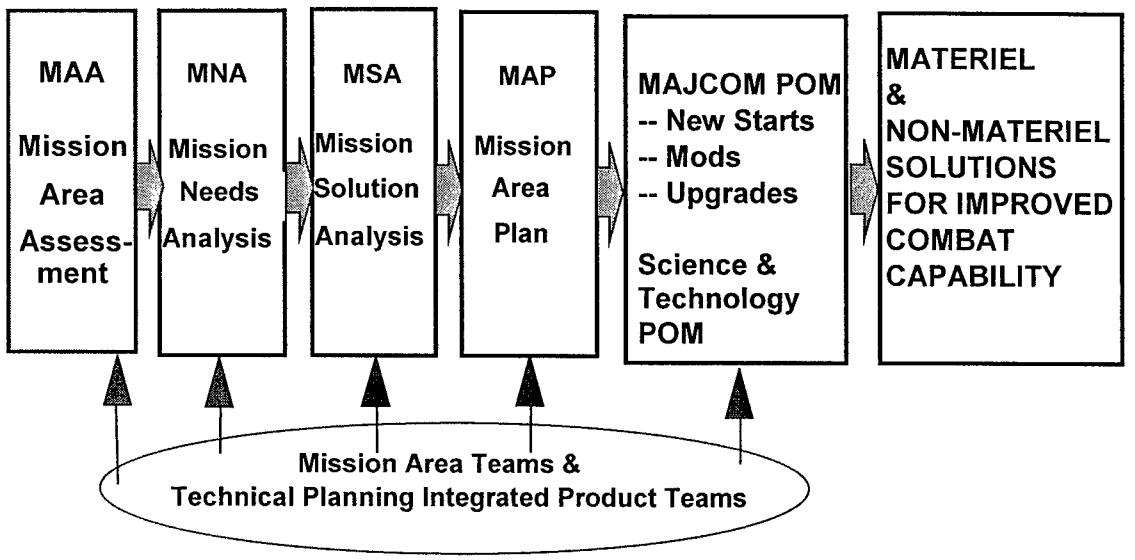


Figure 19. Notional view of AF Process flow

In the Air Force, each MAJCOM[29] owns and executes the Modernization Planning Process. The process relies heavily upon the output of the national strategic planning process for guidance. The MPP has a cycle time of two years - from the beginning of the process until every step has been completed. The Air Force introduced the MPP in 1996 as an Air Force Process to make the 'fuzzy front end' of acquisition more definitive and correct some of the deficiencies of the previous front-end system (Weishoff 1990). See Appendix H for more information about the previous system. Air Combat Command has been using a 'MPP-like' process since about 1993. It was institutionalized in the Air Force by 1996. The process incorporates the use of the 'Strategy-to-Task' methodology. The actual form of how the Air Force has implemented this methodology exists in the Modernization Planning Process (MPP) Flow. One of the unique features about the MPP is the extensive

[29] An organizational structure in the Air Force organized around specific mission tasks (e.g. Air Combat Command, Air Mobility Command, Space Command, etc.).

participation of the Acquisition System in this portion of the front-end. This kind of participation will not occur again until near the end of the front-end process. This diagram depicts the Air Force MPP flow.



(Stewart 1996)[30]

Figure 20. Modernization Planning Process Overview

Mission Area Teams (MATs) and Technical Planning Integrated Product Teams (TPIPTs) are the individuals that put the MPP into practice. They are responsible for the products of the MPP that lead to recommendations for the MAJCOM Program Objective Memorandum (POM) as well as the Science & Technology POM. They are charged to develop non-materiel and materiel solutions for known needs, deficiencies, and capability shortfalls. The MATs are made up of experts at the Action Officer level. A Colonel in the Planning office at the MAJCOM leads the teams. By definition, these teams are 'warfighter'-led with acquisition community participation. There are currently 16 MATs[31]

[30] This reference gives the official US Air Force guidance on the MPP (USAF 1996).

[31] The AF Mission Areas are: Airlift; Specialized Mobility; Air Refueling; Information Protection; Psychological Operations; Counter Information; Surveillance & Reconnaissance; Space Force Enhancement; Theater Battle Management; Training & Education; Aerospace Control; Space Control; Space Support; Strategic Attack, Interdiction, Combat Air Support; Space Force Application; and Special Force Application.

and a corresponding number of TPIPTs[32] across the entire Air Force. (These are not completely aligned one for one and an effort is underway to align these.)

The MATs begin by conducting a Mission Area Assessment to determine the needs in that team's mission area using the previously mentioned Strategy to Task methodology. Once the needs are known, the MATs conduct a Mission Needs Analysis to define the existing state of capability of the US Air Force in that mission area and identify deficiencies in capabilities required to fulfill those needs. The next step is Mission Solution Analysis. Its purpose is to find potential solutions, both materiel and non-materiel, that will fulfill the need. The outcome of this stage is presented in the Mission Area Plan (MAP). The MAP contains the documented progress and outcomes of the MPP for that particular mission area. Of most importance are the proposed solution concepts, including tentative resource requirements (such as cost and schedule) for those potential solutions, both materiel and non-materiel.

The proposed solutions are generated during Mission Solution Analysis. Although the MAT oversees MSA, most of the work is done by a TPIPT from Air Force Materiel Command (the Acquisition Community). TPIPTs provide analytical, system engineering and acquisition-related support to the user during all phases of Modernization Planning (Siewers 1997). The purpose of the TPIPT is to provide unbiased recommendations for materiel solutions to needs identified by the MATs. A designated chief who is assigned a core team of full-time personnel leads the TPIPT. In addition to the core team members, the TPIPT is comprised of personnel from many organizations and functional backgrounds, including System Program Offices[33] (SPOs), Air Force and national laboratories, industry, warfighters, and planners. The TPIPT Chief is also a member of the corresponding MAT who supports the MAT during the entire MPP, with particular emphasis on the MSA (Siewers 1997).

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[32] The names of these TPIPTs as of 4 Aug 98 are: Air Superiority; Air to Surface; Aircrew Training; Mobility; Special Operations Forces (SOF); Agile Combat Support (ACS); Command & Control; Intelligence, Surveillance & Reconnaissance (ISR); Weather; Information Operations; Environment, Safety and Occupational Health (ESOH); Education and Training; Crew Systems; Space Control & Space Force Application; Space Force Enhancement; and Space Support.

[33] The System Program Office is where the development and acquisition of systems is conducted and/or managed. A SPO exists only when a weapon system has entered full development.

As soon as needs begin to be identified during the Mission Needs Analysis, the TPIPT is already at work preparing 'Concept Calls[34]' to determine ways to fill those needs. The Concept Calls are sent to those in industry, Air Force and national laboratories, and the public that demonstrate an interest in working on a potential solution to a need. This activity includes interfacing with concept developers to help mature potential solutions. As solutions from the Concept Calls are evaluated, the TPIPT works at assessing the technology of the solution, identifying technology needs and development programs to support potential solutions. These are documented in the Technology Action Plan (TAP). By-products of the effort to identify mature technologies are TPIPT recommendations for transitioning these technologies to existing programs and SPOs. The TPIPT works on developing programs to facilitate prototyping and the demonstration of advanced concepts as well as interacting with other TPIPTs to identify common solutions.

Specifically, TPIPTs do the following things during Mission Solution Analysis. The TPIPT conducts concept identification and assessment for its particular mission area. (QFD is most often used by TPIPTs in their assessment activities.) The TPIPT will identify, consolidate and analyze materiel solutions to identified deficiencies and needs, and also document detailed descriptions of the concepts, analytical methodologies, results, and associated concept development roadmaps and technology needs in the Developmental Plan[35] (DP). The DPs are linked to the appropriate MAPs, Technology Action Plans (TAPs), and existing Weapon System Master Plans[36] to identify the critical technology needs. The TAP provides a framework to be used by laboratories and industry to identify and assess various concept technologies. Additionally, the TPIPT will identify appropriate technology projects and demonstrations to assess these technologies (Siewers 1997).

After all of the potential solutions have been evaluated (which is a form of prioritization), the MAT determines which of the solutions will be documented in the MAP. The relationship between the MAT and the TPIPT is not simple nor can be described in a serial kind of relationship. The MATs

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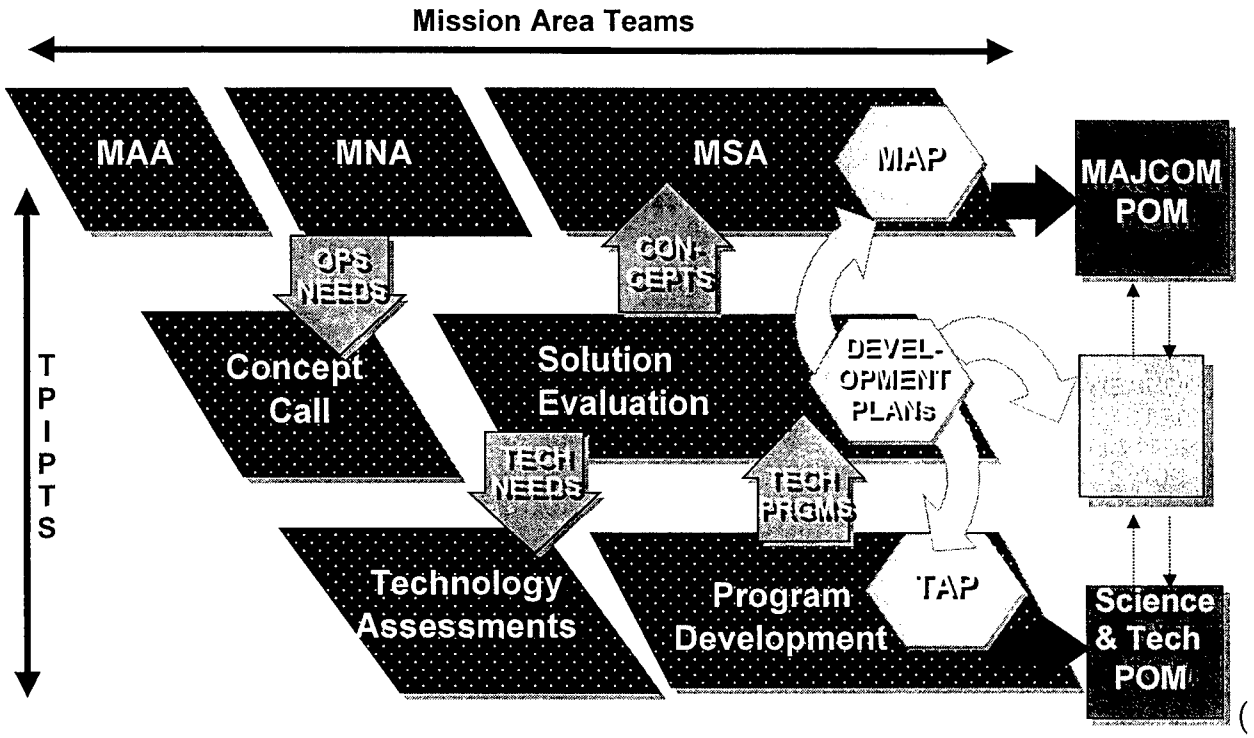
[34] A Concept Call is a formal request or solicitation by the Air Force, usually printed in the Commerce Business Daily, for industry to present potential solutions in a given mission area. The Call contains all pertinent instructions about the content format, the presentation style, and also the protections in place for company proprietary information. Most concept calls have no funding associated with them – so any participation by industry is voluntary and without remuneration. Most companies view these calls as essential marketing opportunities – in a few years their company's concept could be the next big purchase by the Air Force.

[35] Development Plan - A product of the TPIPT. It contains the results of all of the detailed solution analysis.

[36] These are plans regarding the future development and modernization of existing weapon systems.

and TPIPTs are always in some phase of action to support one part or another of the MPP. In some respects, the MAT provides the broad focus for the MPP and the TPIPT provides depth to the process in the form of detailed analysis.



Stewart 1996, pg.10)

Figure 21. Relationship of Technical Planning Integrated Product Teams (TPIPT) to the Mission Area Teams (MAT) of the Modernization Planning Process

Although the programming and budgeting portions of the PPBS rely upon the planning function for input, the Requirements Generation System of the Air Force is first required to validate and approve new 'requirements' that will go into programming and budgeting. This requirement is one of the checks and balances in the system. In order for an item to be programmed or receive money in the budget, the requisite MNS or ORD must be approved by the RGS, otherwise the money cannot be allocated and is usually redirected. Nevertheless, programming and budgeting events take place outside of the overall Requirements Generation System and will not be discussed here. This process within the Air Force is outlined in Appendix D. It is equally important to remember that there is typically a two-year lag between programming some item into the POM and getting the money to

spend during any fiscal year. The MAP, therefore, serves as the link between the MPP and the RGS. Therefore, the Requirements Process is just one of several systems working together, but acts as a sort of gate-keeping function. The other processes (PPBS and Acquisition) are unable to proceed 'officially' in development activities until the Requirements Process takes action by approving and validating either a MNS or an ORD.

AF/XO is the Directorate of Operations at the Headquarters Air Force. XO is the process owner for the entire Requirements Generation System. XO's responsibilities are for day to day operations – in essence, this directorate represents the end user and the end user's activities in the Air Force. Similar organizational structures exist at the MAJCOM level for Operations. These groups 'own' the Requirements Processes at the different MAJCOMs. Besides directing the authorship of the document, the Requirements System mandates a series of reviews to ensure the 'need' or requirement is valid. The indicated schedule for processing, validation and approval for each document is contained in the Air Force Instruction (AFI) 10-601, which defines the Requirements Generation System of the Air Force.

Generally speaking, the document writer is an Action Officer (AO) at a MAJCOM in the Operations Directorate. The AO is usually directed to write a Mission Need Statement for a particular issue. Typically, the AO finds the most recently approved MNS or ORD and uses it to be a reference or baseline for the document being developed. However, the MAP is not necessarily consulted in writing a MNS (although it should be according to the directives governing the overall process). Often, the AO is also serving as a Program Manager[37] or Program Element Monitor[38] at the MAJCOM. As such, these individuals are extremely busy in their current capacities; they do not have the time to consult a MAP for deficiencies. They often gather user needs and requirements directly from the users in the field, sometimes holding Requirements Working Groups according to their particular job duties, mission areas and users they represent. These working groups also try to prioritize their needs according to their perception. No formal study or methodology is used to prioritize these needs.

[37] The Program Manager represents the user in the day to day interactions between the end user and the Acquisition Program Manager of a given weapon system.

[38] A Program Element Monitor (PEM) is responsible for monitoring the funding in a given 'element' or system classification according to the PPBS. Typically, the PEM has oversight responsibility over several similar programs (i.e. all tanker aircraft), and ensures that the different kinds of funding are properly spent and that funding deadlines are met. (Not all money is the same in a program – some kinds of money must be spent within one year of receiving it, other types have up to five years to spend it.)

These needs are also usually expressed in the format of a specific solution. With this information, the AO searches for existing ways to deliver (fund) the solution. If modifying a given program can fulfill the need, and the modification costs do not exceed the cost thresholds outlined by the Requirements Guidance (see Appendix I), money will be sought from that source. Otherwise, the AO searches for an approved MNS or ORD that already addresses the need. If no MNS is found, the AO will begin to draft a Mission Need Statement. (If a MNS has been found that addresses the situation, but is not in development due to a lack of funds, finding resources to pursue the development of that MNS becomes the primary driver. The AO may also begin to write a draft ORD in parallel to finding resources to expedite the process.) After the document has been drafted, it must be coordinated though the staff of the MAJCOM and then comments must be resolved. This is actually one of the primary filters for ideas. If all of the different organizations[39] at the MAJCOM do not 'buy into' the idea, the effort essentially dies. In cases such as this, the AO may initiate briefings with many of the organizations to demonstrate the importance of the issue and put new life into the effort. Assuming all comments are resolved and the MAJCOM Commander approves the document, the MAJCOM will release the document to the Headquarters Air Force.

The staffing and schedule beyond the MAJCOM includes four phases and five milestones. The first milestone occurs when the MAJCOM submits the draft document to the Headquarters Air Force at the Pentagon. The document is given 45 days of review at the O-6 level (Colonel-level) in various organizations throughout the Headquarters Air Force. These organizations are typically known as Three-Letter organizations. Those reviewers in these organizations act as a 'first-look' for the document before their boss, (the two-letter), gets a chance to review it later in the overall process. When this first review is complete, the MAJCOM receives the comments. The MAJCOM then has 45 days to resolve all of the comments. The MAJCOM will then submit the 'final' document. The document is then sent back through the same staffing and reviewing procedure, with a 30-day time limit. After the same three-letter organizations review and make comments to the final document (and after those comments are resolved), the document goes before the Air Force Requirements Oversight Council (AFROC) for three-letter coordination and recommendation, ('endorsement'), to proceed further in the process (USAF/DXOR 1999). At this point the document enters a final review done by general officers (the two-letters). There is no time limit on this phase, and all comments must be

[39] Organizations that might be impacted such as Plans, Personnel, Logistics, etc. must verify they can accommodate the new requirement.

resolved before the document moves forward in the process. (Typically, the two-letters take no exception to the endorsement of the AFROC.) When this review is complete, the document is sent back to the MAJCOM for the Commander's signature. At this point, the document is signed by XOR and sent to the XO (two-letter) whose signature constitutes 'validation' of the document. Once 'validated', the document is sent to the Chief of Staff of the Air Force (CSAF) for a signature. The document is then 'Approved'. (Rarely, if ever, has the CSAF failed to sign a 'validated' document.)

Note: the validation authority changes according to the ACAT level. Accordingly, ACAT I documents are 'recommended' by the XO to the CSAF for approval to proceed into the Joint validation and approval process. When the CSAF 'approves' the document, it enters the Joint Staff review, validation and approval process. The document remains at the Joint Staff until all comments have been resolved and the document is approved by the JROC[40]. ACAT II documents are validated by the XO. ACAT III documents are validated by the XOR based on the recommendation of the AFROC. The CSAF, however, approves all documents. For more information about the actual process flow for document validation and approval, see Appendix J.

The XORPD Web site, http://www.afreqs.hq.af.mil, (a .mil restricted web site), as of December 30, 1999, has a briefing entitled "The Life of a Document" that illustrates the process in graphical detail. This process is followed for each document for a given system (i.e. both for a MNS and an ORD).[41] Rarely does this process meet the mandated time frames.

Once a MNS has been approved (the PPBS has the funding in place and the Acquisition System makes its Milestone 0 Decision), the MAJCOM proceeds with an Analysis of Alternatives. This is a formal study that seeks to evaluate all potential alternatives to the preferred solution to the need indicated in the Mission Need Statement. The MAJCOM Studies and Analysis group either conducts these studies or it is awarded to a contractor. Depending upon the complexity of the contemplated system, the AoA usually takes between six months and eighteen months to complete. The final product of the AoA is a recommendation for a solution. Included with this recommendation are

[40] Suggested time frames for the joint process are found in the regulation governing the joint requirements process (CJCS 1999).

[41] In the fall of 1999, a change was made to AFI 10-601 deleting the need for a MNS for potential Acquisition Category (ACAT) II or III programs, so long as a product of the MPP had validated the mission need. The AFROC would generate an AFROC Staffing Memorandum (AFROCSM) recommending validation and approval of the mission need to the appropriate authority. Furthermore, the two cycles of review at the Pentagon were reduced to just to one round for all documents (USAF/DXOR 1999). Review (USAF/DXOR 1999) for information about Requirements and ACAT levels.

certain key performance parameters that are required for the system to meet. Additionally, trade space on other requirements is identified in the form of threshold and objective requirements.

To help with the quality of AoAs, the Air Force established an Office of Aerospace Studies (OAS) that acts as an independent consultant to a MAJCOM about conducting AoAs. This office has no authority over the AoA, nor can it pass judgement on the quality of the AoA. OAS does not even have to be involved if the MAJCOM chooses to exclude them.

The Air Force has approximately 1000 individuals that are engaged in Requirements development. There are approximately 100 Requirements documents that are approved each year. About two-thirds of them are Mission Need Statements and the remaining third are Operational Requirement Documents. Regardless of the processes used at the Major Commands, the overall cycle time for these documents, whether a Mission Need Statement or an Operational Requirement Document was 430 days. However, some documents have gone through the system in as few as 90 days (particularly if they have 'high-leadership interest'), as well as some documents that have required well over 700 days to complete the process. If analyzed in a serial fashion, the overall cycle time from the writing of the Mission Need Statement until an Operational Requirement Document is written and approved (including an average Analysis of Alternatives (AoA) time of 18 months) is approximately 4 years, (with variations from 1 to 10 years). This also assumes the processes are in-sync with the programming phase of the PPBS and that the money required for an AoA (and program start at Milestone I) is immediately programmed correctly. If all of these items are done correctly, only an additional two years are added. This also assumes that the required political forces are in place to allow the effort through the entire front-end process. Finally, the MPP at the beginning of the process requires approximately 2 years to indicate a need exists before a MNS is written (USAF/DXOR 1999). Therefore, the overall cycle time of the entire front-end[42] (executed in an ideal fashion as the current system is designed) is about eight years, (with variations from 3 to 15 years).

Furthermore, a great deal of variation exists among the MAJCOMs of the Air Force concerning the degree of adherence to the guidelines of the Modernization Planning Process and Requirements Process. This information is presented in the table below. 'Existence' of the process is defined by functional departments within organizations tasked to accomplish the requirements of the process.

[42] For another view of the entire front-end process, please see Appendix K.

'Maturity' is defined by the MAJCOM taking steps beyond those found in the official guidance to improve the relationships and/or interfaces between the Modernization Planning Process, the Requirements Generation System, and the financial aspects of the Planning, Programming, and Budgeting System[43].

Table 15. MAJCOM Process Maturity

Process Maturity	MAJCOM					
	A	B	C	D	E	F
Modernization Planning Process exists	X		X	X	X	
Modernization Planning Process is mature	X			X		
Requirements Generation System exists	X	X	X	X	X	X
Requirements Generation System is mature	X			X		
Planning, Programming, Budgeting System exists	X	X	X	X	X	X
PPBS is mature (Fiscal constraining of MPP for FYDP)	X			X		

Despite the noted differences, the average process times (in the case of document development, validation, and approval) displayed no notable differences[44] between the 'mature' processes and those that were not. There also are no measures available or recorded relative to the overall process yield (i.e. how many needs identified in the MPP actually are funded and get to program launch or Milestone I). One MAJCOM provided the following information on the partial process yield for the FY02 POM: of the 646 needs (with a conceptual solution identified through the MPP) only 29 or 4.4% of them were placed into the MAJCOM POM. Of that number, zero survived into the Air Force POM. It was not known how many of these needs were simultaneously being prepared by the Requirements Generation System. As one interviewee noted, "These things change hands so often, you never know what happens to them."

Organizational Issues

The Air Force front-end contains many duplicative functions between the headquarters and the MAJCOMs. The duplication is not so much an issue as between MAJCOMs with legitimately

[43] The ties to the Acquisition system were not addressed because they do not become actively involved in the process until after the MNS is validated.

[44] The quality of the Requirements Document could not be measured – it was deemed too subjective & difficult to quantify. However, anecdotal evidence delivered orally by various interviewees indicates quality is a factor. For instance, many documents are written in the language of the operating environment (e.g. space) and are not written to be read or understood by the entire Air Force – particularly important during a document's coordination and validation phases.

different missions; rather it is between the duplication of effort between all of the MAJCOMs and the headquarters (each has Modernization Planning, Requirements, and PPBS functions). Each organizational group has an organization dedicated to the PPBS (and the MPP within the PPBS) and the Requirements Process. There does not appear to be any integrative structure within the process outlined. The only integrative effort similar to a business case decision that occurs is during the Air Force Group review in the PPBS structure (see Appendix D).

There are multiple reviews and screens within the process. The process is designed with these in mind, but it is not clear what the value added to the document is, except that anyone who wants to know what is going on, is able to.

TPIPTs seem to be the team that actually develops solutions. Rather than allowing them to continue their efforts – and potentially build a business case – the concepts and responsibility from them are taken out of their hands and are developed through the MAT and then eventually through the person that actually decides to write a Mission Need Statement. It would appear the TPIPTs represent the technological professionals and the MATs and Requirement document originators are simply end users. Also unusual is the current cool reception TPIPTs are now receiving. AFMC has not placed much emphasis on them. In fact, there are some TPIPTs that exist in name only because there are not enough personnel and resources to function in TPIPT positions. Funding for these TPIPTs also seems to be a point of contention. The MAJCOMs do not want to provide resources, and AFMC does not either. The specific funding element in the Air Force for pre-Milestone 0 studies, PE65808, has virtually no funding at all. Interviewees, particularly those who write MNS and ORDs, expressed many comments that TPIPTs exist to only follow the whims and desires of the 'pocket-protector' wearing acquisition personnel and that they provide no real value. However, people within the Planning community did not echo these sentiments. They are dependent upon the TPIPT for inputs to the MPP. These perceptions highlight disconnects between the Modernization Planning Process and the Requirements Generation System.

The Air Force MAJCOMs interpret governing guidance and regulations differently and therefore, some MAJCOMs have a very formalized MPP, while others have none at all. The same is true for the staffing guidelines in RGS as well.

Upon completion of the AoA, an AoA Report is published. This report serves as the primary input to the Operational Requirements Document (ORD). While the AoA is still in progress, it is typical for a draft ORD to already exist and as more results are known from the AoA, the draft ORD is updated. This is partially done to eliminate delay time from the completion of the AoA to the approval of the ORD. Unfortunately, some ORDs have been through the entire review and validation process (identical to the process used for a MNS) before the AoA is completed or the ink is dry on the AoA Final Report. Additionally, pressures of time (to reduce the amount of time required to begin a system's development) and other resource constraints (no money programmed or not enough time to get money for an AoA programmed) have led to the proliferation of 'AoA-like' studies. Bluntly put, these are quick efforts that do not go into the depth of analysis and detail that an AoA would. The quality of these studies is likely to be equally diminished.

Business Issues

There is no formal business case developed by the RGS. The closest thing to such a business case exists at Milestone I during which very rough costs are presented, but funding decisions appear to be based solely upon total costs and the ability to fit a program within the current fiscal environment. Furthermore, individuals who do not participate in the Requirements Process and have little insight into the Requirements Process make these funding decisions.

The Air Force has multiple databases and IT capabilities, but they are not integrated. About the only thing standardized within the Air Force are email address naming conventions and using the Microsoft Office Suite products.

The Air Force does not consider the costs associated with the existence of the front-end system, whether in terms of personnel costs, nor in terms of the opportunity costs (e.g. requirements that become dated and are no longer as valid or correct).

Modifications to existing systems are also covered by regulation. Since the relative number of new programs is dwindling (lack of money, etc.), the pressure to modify existing programs and systems has only grown. These modifications also consist of requirements and are handled by the Requirements System as well. However, because these programs already have funding secured, the time between a Requirement Document's preparation and the execution of the requirement is much shorter than

using the process for a 'new' requirement. Most MNSs and ORDs today have been developed this way (and contrive links back to a MAP). This seems to be the preferred method of requirements generation in the Air Force. Again, this highlights the differences between the Modernization Planning Process and the Requirements Generation System. These differences also tend to strengthen the relationships between the TPIPT and existing SPOs.

Summary

Clearly the Air Force has a formal process. However, it is disjointed and the processes do not seem to support one another. A team rarely develops requirements; rather it is an individual tasked by the organization to write them down. They are corrected, modified, and clarified by means of the exhaustive review and approval process.

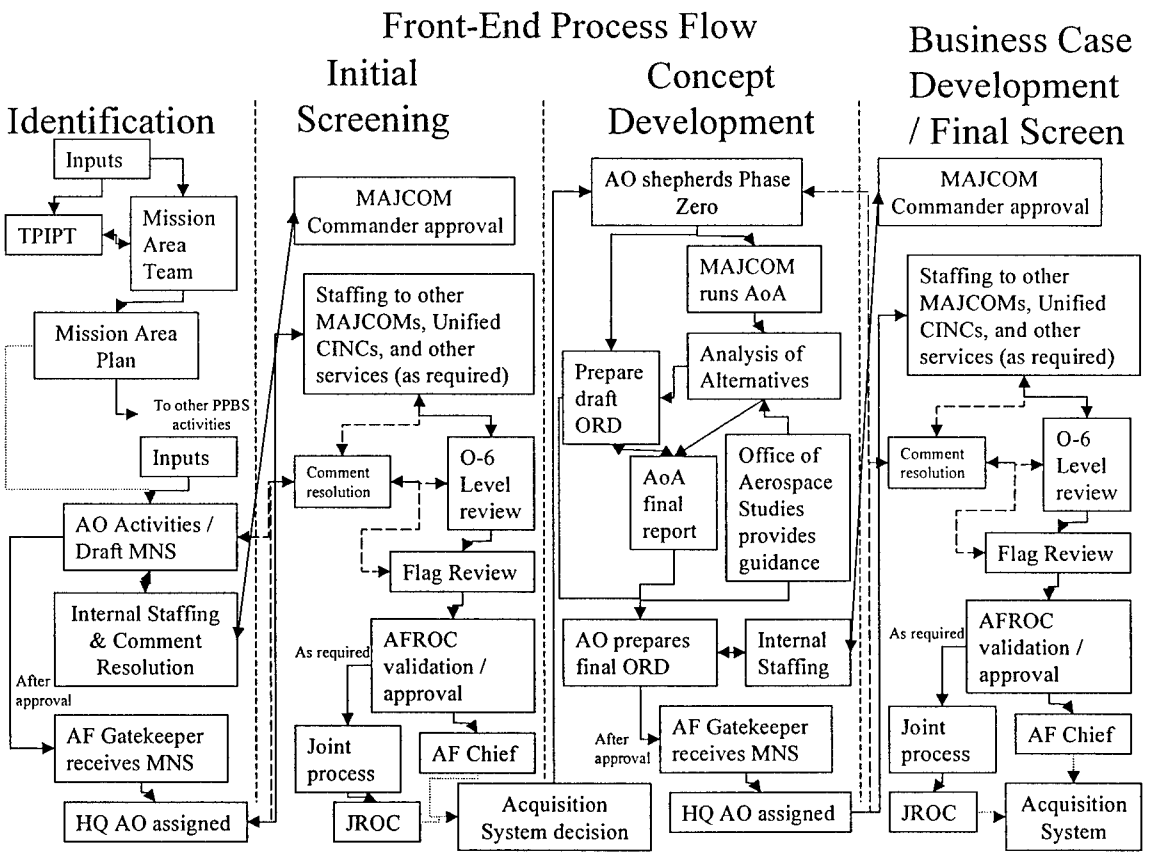


Figure 22. Air Force Front-end Process in Terms of the Framework

The process diagram highlights the major process disconnect between the actual MPP and the 'Requirements Process.' A closer look at the process in terms of screens and approval forums reveals there are 3 formal screening functions and two approval forums within the Air Force alone. The overall process including the joint process has a total of 5 screening processes and two approval forums. Both Mission Need Statements and Operational Requirement Documents follow this process.

The process accepts multiple input from various locations. Interestingly enough, most of the inputs to the ideal Modernization Planning Process (MPP) are also very active at the Requirements Organization. This representation is actually an oversimplification. Most of these inputs are being made in a variety of areas, from convincing the end user concerning a potential product to invited presentations at the MAJCOM Headquarters. If the user, for example, can convince the Requirements community of the validity of the need, the Requirements community will exert pressure on the Modernization Planning Process to 'identify' the need. Also, opportunities to circumvent the process exists when the Requirements Community uses wide latitude in correlating an identified need with the 'requirement' in the process of being validated. The governing instructions and regulations for the Requirements process allow multiple MNS and or multiple identified needs within a Mission Area Plan (MAP) to be the basis for an ORD.

The process requires at least 8 years to get through in a serial fashion and there is a great deal of pressure to use other methods to circumvent the process. Concurrent Engineering is the term used by the Air Force to describe parallel activities. It is not uncommon to see these things happening in the front-end as well.

There are alternative processes to the normal Requirements Process, the RRP and SMART processes. However, these are bound by a certain set of restrictions. The RRP process must have an overwhelming requirement that demands immediate attention. This really occurs only during conflicts. However, the RRP is the only way that a Warfighting Commander-in-Chief (CINC) can directly submit a requirement into the process; normally, these must go through a MAJCOM (as per Federal law). The SMART process is really only for those systems that are ready to go into production immediately. Additionally, these systems must already have funding identified and secured from another source for at least two years until the program can be incorporated into the MAJCOM POM

(usually coming from a MAJCOM's discretionary funding) (USAF/DXOR 1999). Finally, the last groups of programs/systems/ideas that are exempt from developing a MNS for the Requirements Process as described are those Communications and Information mission needs with a projected program cost of <$15 million. They will use a Communications and Information Systems Requirements Document (CSRD) as a MNS IAW AFI 33-103, Requirements Development and Processing (USAF/DXOR 1999).

In the course of this analysis, this was one subject that came up that is outside the scope of this effort but is worthy of mention. There is a great deal of product development that occurs within the Air Force, particularly software development, that falls under the discretionary funding of a MAJCOM or other organization commander. This type of development does not require any kind of requirement documentation such as a Mission Need Statement or Operational Requirement Document. The development of software may be worthy of a MNS or ORD, but the discretionary funding regulations do not require it. These programs are governed by a separate set of instructions. The form required is a Communications-Computer System Requirements Document (CSRD) which is used to identify Command, Control, Communications, Computer and Intelligence (C4I) requirements less than $5Million dollars. They are processed through a separate system whose main concern is ostensibly on system interoperability (but probably just operability) and not on overall program necessity.

Some of the Air Force Acquisition Product Centers (there are three of them) have centers that develop and maintain software. When MAJCOM 'home-grown' software developments run into trouble, the Product Centers are petitioned for help. This results in the creation of a Service Level Agreement (SLA). These SLAs are as large as $2 Million dollars per year, and are on average about $1 Million dollars per year. None of these come under the scrutiny of the Headquarters Air Force. Individually, these SLAs are too small to warrant any attention, but the program size can be deceiving. Each SLA can be renewed yearly, as needed, to support a given software development. Some of these SLAs have been going on for years. These yearly agreements are considered 'new efforts' by the 'system' (the PPBS) and the governing guidance.

At one Product Center alone, there are about 300 active SLAs and another 200 more in sustainment. Both of these types of SLAs deal with requirements. The active SLAs are in the development phase of the software application and requirements (i.e. functionality) are at the core of the process. The

sustainment SLAs take care of missed functionality, bug fixes, and enhancements that also form a type of requirements management.

Despite the small size and nature of these SLAs, at this product center alone, there is more than $100 Million dollars per year spent through these agreements. If they were counted as 'one' program (i.e. Miscellaneous Software Development) with multi-year funding, over a five-year period it would be more than $500 Million dollars – exceeding the threshold required to qualify as a Major Defense Acquisition Program (MDAP) and fall under the purview of the Requirements Generation System.

As an example of the issue surrounding software development and their requirements, one organization started a program to automate a common task. After spending over $45 Million dollars (via discretionary funding and over an unspecified amount of time), the effort was in so much trouble, a product center was asked to help. The product center recommended scrapping the program entirely because it was so poorly architected. A SLA was made and within a short period of time (unspecified, but indicated as substantially less than the first try) and for much less money (again unspecified), the product was delivered to the customer (MAJCOM).

CHAPTER 6 - ADDITIONAL CASE STUDIES

The companies chosen for the other case studies possessed either one of two qualities or both. The major quality was that the companies chosen dealt with product development issues that were extremely large, complex, and technologically advanced, as are most military, particularly US Air Force product development projects. The second quality was that these companies have been recognized as being rather successful in their front-end processes by other reputable consulting firms, particularly those that consult heavily in the product development niche.

Commercial Companies

There are eight commercial companies presented. They include companies that deal directly with other manufacturers, end users, and regular consumers (or any mix of those three). Two companies are primarily manufacturers of product development activities and deal only with end users. Another two companies primarily are purchasers of manufacturer's products (i.e. they are end users (and not average consumers)). Three companies are producers that have an equal mix of approaches to the three kinds of customers listed above, and one company is focused solely on the front-end (It is the product development organization for a larger manufacturing company.)

All of these companies display analogues similar to existing military organizational relationships.

Company A

Company A is a large chemical applications company with headquarters in the Northeastern USA. It has a formal Product Development Process. This process is documented in a written plan. It was developed within the past five years, taking the best pieces from their different business units' planning processes, (most of which were recycled from a major US Automaker's Quality Plan), the parent company's product development process, and inputs from their Program Management department.

The company cites two major reasons for having this process: it ensures a steady stream of products (to include Speed to Market, Cost, Quality, and Innovation), and the alignment (alignment of Business Management, Program Management, and R&D, Product Development, and Manufacturing

Operations') it forces. Business Management leads product development. Program Management is viewed as an Enabler for the overall process. The other processes add value to the product.

The following diagram indicates Company A's front-end processes.

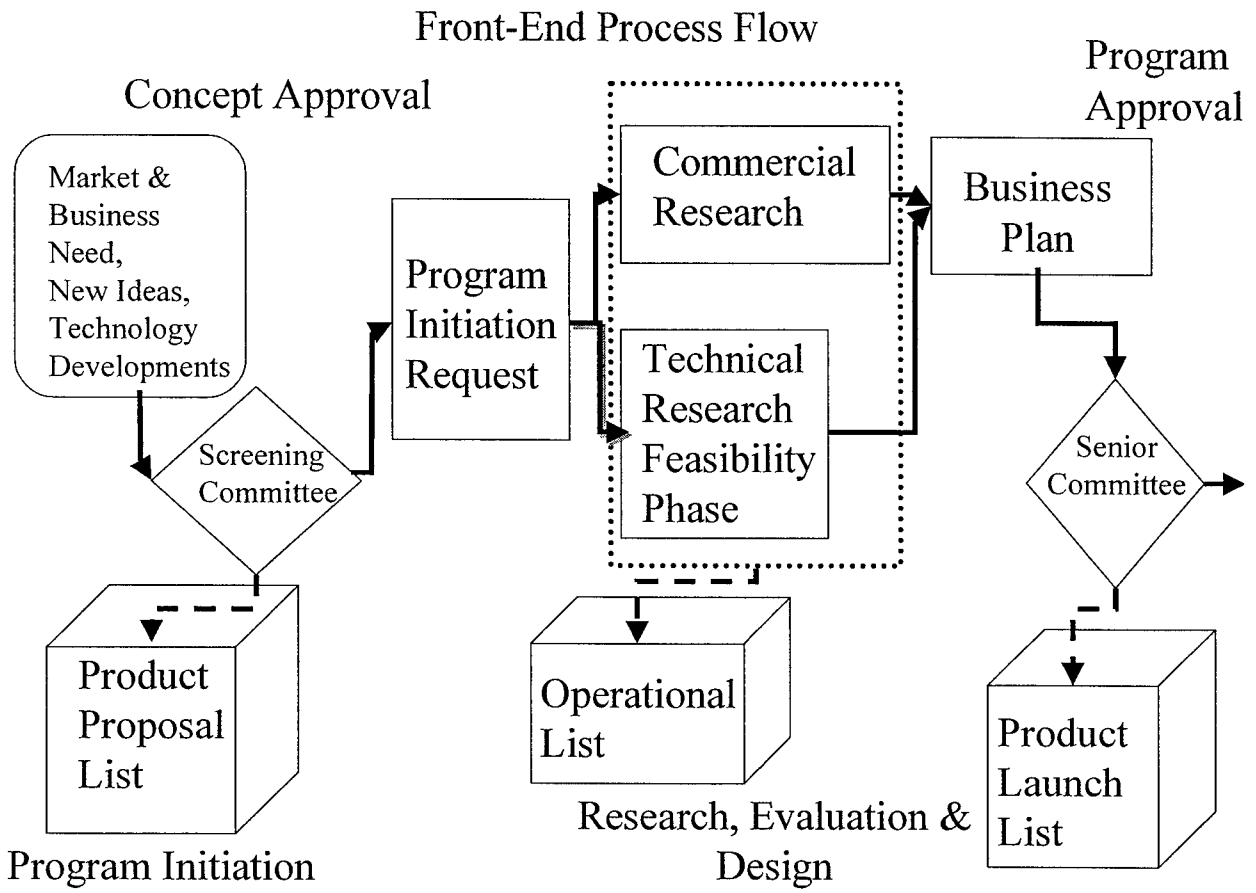


Figure 23. Company A's Front-end Process[45]

The two-stage process (Concept Approval, Program Approval) depicted above adds structure and robustness to a typical Stage-gate Product Development Process. The specific activities during these stages will be described in the following paragraphs.

[45] Adapted from the company's formal product development process plan.

Overall, the company's New Product Development Process has five phases: Program Initiation, Research Evaluation & Design, Product & Process Development, Product & Process Qualification, and Feedback. The process also has three approval stages: Concept Approval, Program Approval, and Product Launch. Program Initiation correlates with the framework's Identification of Requirements stage. Research Evaluation & Design Phase correlates with the framework's Concept Development Phase. The Concept Approval Stage correlates with the framework's Initial Screening Stage. The Program Approval Phase correlates with the framework's Business Case Development / Final Screen Stage.

For the purposes of this case study, only the first two stages will be explained because those stages encompass the area defined in the idealized framework for the front-end. The other three stages are typical for a stage-gate product development process. Finally, the company uses four 'Lists.' These are the Product Proposal List, the Operational List, Product Launch List, and R&D's Technology List. The term 'List' is more than a list of projects. It is a name for the matrix that describes the portfolio management process of the company and it consists of the project name, the objective, and the market timing required along with schedules of defined activities, etc. Accompanying this information are PowerPoint style charts that further describe the project. This information is stored on a corporate information system or an executive information system. Combining the Product Proposal list and the Product Launch List essentially represents the company's five-year roadmap.

The First Phase is called Program Initiation. There are five sources of information used in this phase: OEM/customer inputs, competitor activity, other data, the strategic business plan, and new ideas. The outputs of this step include the following: an initial Screening Committee review, a Patent opportunity analysis, Consumer/OEM/trade value analysis, a Technology – Manufacturing Opportunity Screen, a Draft Program Plan, and a Feasibility Study Request.

Additional inputs come from several sources. These range from typical marketing activities: like listening to the customer, OEM requirements, and unsolicited ideas from any source (customers, consumers, and employees, etc.). The company will put together a team to do studies on these ideas. More on the team composition will be addressed later. The company has money set aside for these preliminary analyses up-front. The company is flexible and variable in budgets for these teams doing studies as they realize that some unofficial work must be done to get a 'ballpark' figure.

Advanced Business Development is a division of the company that deals not only developing new business through applying technology but also with exploiting technology gaps. It provides seed money for new R&D projects with business potential. Because this company is a platform-based company, technology gaps (as described by the technical literature) are bound to exist in their product offerings. When technology gaps are recognized, and it is something the company will not overcome using internal resources, the company looks outside the organization. The company is aggressive in pursuing 'garage shops', universities, other company's technology through license agreements, etc. However, the decision to pursue these opportunities is done according to the direction of the Screening Committee.

The responsibility for the front-end rests with the Screening Committee. Its members are cross-functional, high-level managers (VP of departments and/or divisions). The Screening Committee determines budgets and it also does the 'Gatekeeping' function. Members of this committee are the Vice Presidents from Technology, Marketing, Manufacturing, Program Management Group, R&D Operations, Original Equipment Manufacturer (OEM) Sales, and Advanced Business Development. The committee is to lead the generation and screening for innovative product ideas and technologies to ensure that products and technologies are prepared to meet the company's short and long-term growth objectives. The committee generates and maintains a list of promising product and technology ideas that generate a continuous stream of new or improved products allowing major product launches at least every two years. If the committee is unable to agree on an item, they defer the decision to higher management. When the committee judges a concept is ready, it is given to program management. The Horizon committee also actively assembles feasibility study plans with the help of the team that began the initial investigation of the idea. There are lots of different activities going on at any given time (in the form of team oversight for the different investigatory teams) and the committee coordinates all of these activities. The Screening Committee is a small group (usually 7 people) and is able to manage and control resource and priority issues. This is the committee's responsibility. The committee has direct access to corporate-level management (i.e. the Presidents of the different company divisions). The committee will take tabs on what had been done since their last meeting. The committee is also empowered to take action if not enough ideas are in the overall development queue.

The company uses teams to put together programs, and these teams follow that particular project until it is put into production and sent to the market. Because of the difficulty involved, they try to negate the difficulties of the front-end by using cross-functional teams or promoting cross-fertilization of teams. The committee believes "the more the market is understood, the better the technology, and the more the technology is understood, the more creative the business." This phrase relates directly to the close relationship between the designers and the marketers. Team sizes may vary, as well as in the discipline and background of the team's members, but there will always be one technical person and one marketing person on each team. Team size will vary on the low end from 2 people and on the upper end from 7 to 9 people.

There is no time limit set or required for the Identification or Program Initiation Phase. The key to this part of the process is having the concept evaluated by the Screening Committee during one of its regularly scheduled meetings. The committee meets every 6 to 8 weeks, where projects are evaluated. During the execution of the company's strategic planning process, the meeting occurs every 4 weeks.

The Screening Committee pushes during the early stages of development (while the idea is still in the identification stage) for small amounts of money to further gather as much information as possible about an idea. The committee looks for a draft business plan, called a Project Brief, before considering to start further development. The brief should define the fundamental reasons why the concept will deliver results according to the company's needs and strategic direction. The project brief is the interim documentation the company will use to track objectives. It documents criteria in sufficient detail for management to approve a design project and includes the following criteria: Primary Project Objectives {Design requirements, key strategies, and milestones}, Resource Requirements and cost estimates {Team members and skills, organizational and technical interfaces, or Special equipment and facilities needs during research and development.} Process Requirements for the new design including critical process characteristics (if applicable), Project Target Completion Date and the Exit Criteria for project completion. It also addresses aspects of the product's Application, Contract Requirements, Cosmetics and Appearance, Cost Estimates, Environment issues, Equipment Requirements, Legal Requirements, Marketing Information (Competitive Situation, volumes, Customer & OEM Input, etc.), Size and Configuration, Safety Requirements, Standardization, Regulatory Requirements, Quality Plan Requirements, Process Requirements, Performance Requirements, and Manufacturing Requirements.

If there is agreement by the members of the Screening Committee, the project brief has sufficiently outlined the resources required, criteria for success, etc. When the committee is satisfied with the progress made on the draft document, it is converted to an approval document. This document is called a Program Initiation Request (PIR). It combines the list of project criteria defined within the Project Brief with a cover sheet where program approval signatures are maintained. Issuance of the PIR constitutes Concept Approval.

Currently, in this stage of the product development process at the Screening Committee meetings, about 100 new product ideas get discussed. Perhaps 10 of these are approved and move forward as a PIR, and an additional 10 to 20 are placed into a low-level consideration category for further investigation. The Product Proposal List contains a list of the approved new product concepts and also is a matrix of the program names and potential launch schedules. Program Management maintains the List for the Screening Committee.

Concept Exploration or Research, Evaluation & Design is the next step in the process. The Inputs to this phase are the previous phase's outputs, benchmarking data, and market research. The Outputs of this phase are mostly form of information: information to report the results of the feasibility study, (product cost targets, timing/schedule, list of special processes, list of critical characteristics); information to specify the Product Specifications, (design targets, quality targets); information to develop a Detailed Program Plan; information to provide an Estimated Program Cost; and a more refined draft Business Plan.

The original team conducts a detailed analysis during this phase. The analysis is simply a targeted understanding of how well the product might do given a set of market assumptions. The Screening Committee will use the analysis to look at the implications of making product development decisions. The criteria to measure the implications come from the strategic plans of the company. When a new idea is given permission to enter concept development to be investigated, the team will form a hypothesis, which it will try to validate with consumers, technical experts, and trade organizations. The time taken for the analysis varies according to the complexity of the issue. Where there is some complexity of issues, 90 days is usual, but more complex issues can take up to 6 months or more. The team will specifically look to see what strategic options there are and how the company can take advantage of them.

New Product Ideas are always addressed from two areas during this phase: a marketing point of view and also a technology point of view. On the marketing point of view, the team tries to understand the market, and anticipate what it will demand. This takes the form of a 5-year look with estimated sales and other market data. According to the company, it is virtually impossible to go beyond that with any degree of accuracy.

On the technology side, the most important question asked is "What would it take to enter the market?" Again, because of this focus on the market, a Cross-functional team has to answer this question. Additionally, the team tries to answer the question of "What does the product have to deliver to the customer?" The team does this beginning with using additional market research and pursuing all available sources of information. During this time, the team will come up with alternate systems and standards. It will pick one or two of the alternatives as most promising and then the team will pass the idea to the technical people within the organization. In this case, the technical people are technically grounded people that are not part of the core team, but are highly respected for their opinions and may come up with different options for the new product. These options can be very diverse. They range from differences in packaging, engineering, chemistry, and others. Furthermore, the core team will try to do even broader assessments. For instance, they will consider the time for development, the 'sweat equity' involved, what barriers exist, etc.

Another one of the outputs of the core team during this phase is the product plan. The product plan has a basic theme – communication to consumers. How much emphasis should be in a certain area, what the nature of the new product should be, what legal and regulatory requirements exist are all elements of this plan. It becomes an important part of the PIR.

Upon completion of this phase, the team prepares the project for review by the Senior Committee. Upon approval, the feasibility study is formalized and it is no longer a draft document. The PIR is approved and becomes the basis for the new program. This information is recorded on the Program Launch List. This list contains products that have been approved for implementation and launch, additionally the list contains potential launch schedules for each program. The newly approved program then enters the company's Product & Process Development phase, which is the beginning of the company's stage-gate product development process. Their cost thresholds for new products range

from $300 M to $1 Billion. Anything more than that becomes an issue for the parent company to handle.

Organizational Issues

The company has no formal training plan. It is done on an 'ad hoc' basis. Usually an outside consultant is brought in to work with a specific team. The company also feels that every employee is keyed into the same NPD issues that management is. Promoting company values, offering incentives to develop new products, and using recognition/rewards programs does this.

Business Issues

Additionally, the Screening Committee mentioned earlier oversees R&D as well as the planning process. Separately, Research & Development does research according to its own agenda. It is not necessarily tied to the strategic plan or vision of the company. This strategy is done on purpose. R&D is charged with the development of new technologies and to track new process techniques. Although they are independent, the company believes R&D does its work with some sense of what long-term issues are. For instance, R&D often uncovers with interesting ideas with possible market potential that would not be found through other conventional methods. These ideas go to the marketing to see if a new market can be created.

Beyond the basic research R&D is involved in, R&D is also responding to technology-pull from the Marketing department. R&D and Marketing agree on a Technology List. The List consists of R&D and also major development products. The New Product List contains those products that will be delivered to market within 2 to 4 years. Usually, the New Product List contains overall objective statements for the new products (e.g. performance increased by 10%, removal of environmental hazards, etc.).

This company's Annual Strategic Planning Process coordinates all NPD activities. It is the first major input into the product development process besides NPD ideas. Strategic planning gives direction, subtle changes, with occasional big changes (corrections), mission statements, etc., for the whole company. It examines what the broad corporate priorities are, and what part of the business they should be in. It discusses any key issues, concerns, and other items of value to the company.

The annual planning process proceeds in the following manner. It consists of a document. Many of the items are repeated from the previous year. The document contains the vision consisting of broad issues and direction on how to proceed including improvement actions (along with resources identified to do it). Major new products are part of the plan. The document is actively used. The plan might have a general strategy for a new product, and then may evolve to a specialized strategy in subsequent iterations of the strategic document. Planning is a continuous process. Another issue the company is focused upon revolves around how to make sure this kind of validation has not been done somewhere else. In terms of the importance of speed of getting products to market, management communicates the importance of New Product Development and time to market to employees through the planning process as well as other means.

The strategic planning process begins at the beginning of the company's fiscal year. The process needs to be done five or six months later. However, due to market pressures, now it is not uncommon for it to be completed in just four or five months. The process starts with new budgets in place for the coming year. Before the end of the month, the Technical List is given to the Operations Committee and Business Management. Over a two-day period during the following month, Business Management develops Strategic Options. Early the next month, the Preliminary Product List is reviewed. Late in the following month, the Lists are sent to the Operating Committee. About 1 month later, the official response to the Lists is given. At the five-month point, the process marks the release of the 'Final 6-year Lists'. Approximately two months later, the Strategic Business Plan is sent to the CEO. On the first day of the ninth month into the fiscal year, the budgeting process begins and the various budgets for the different business units are finalized just prior to the end of the fiscal year.

Summary

Company A process generally follows the concepts of the notional framework. In the process of identifying requirements, Company A was very adept at using multiple methods to gather these requirements. The company follows a formal process for doing so and uses a lot of market research and analysis.

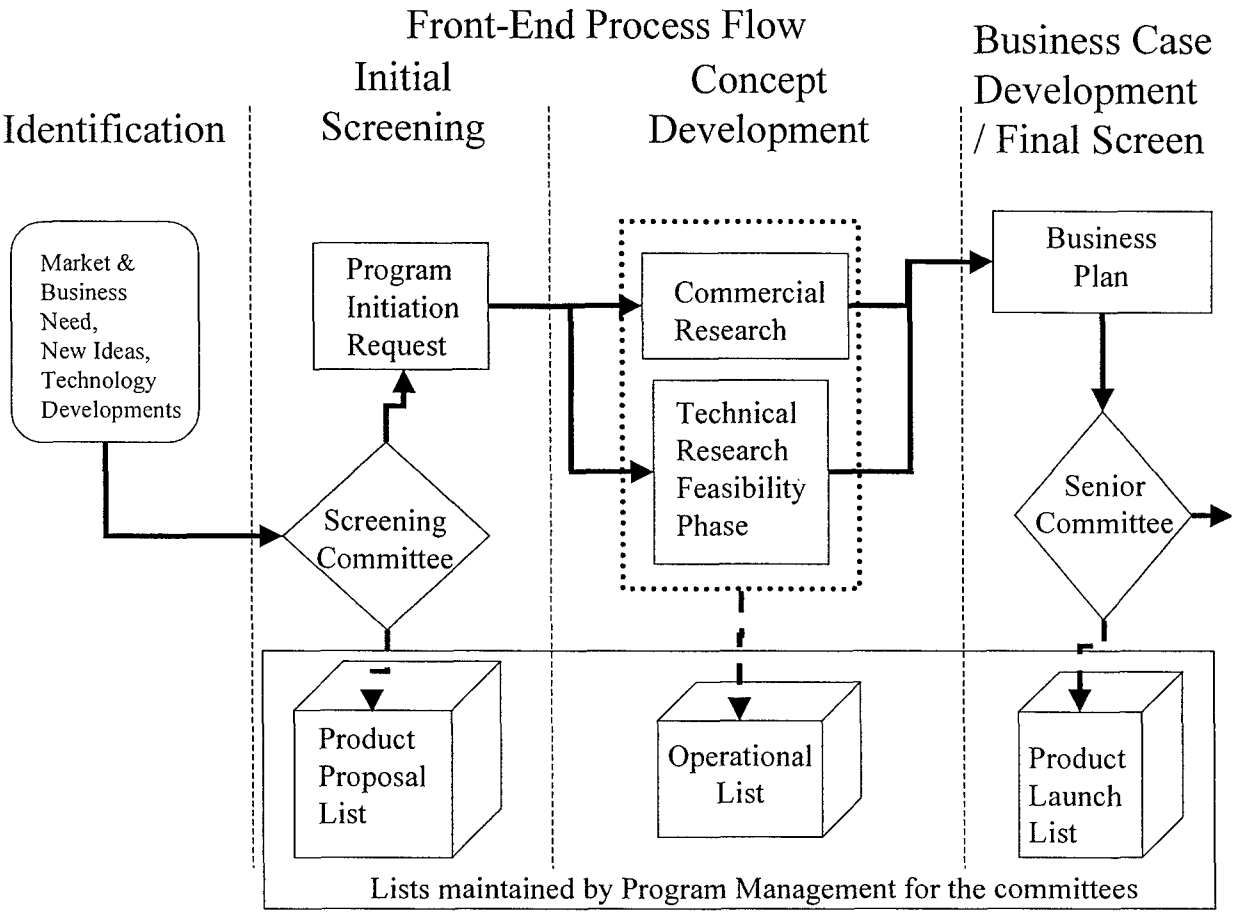


Figure 24. Company A's Front-end Process in Terms of the Framework

The company uses a screening process very close to the idealized one proposed in the framework. Their use of the Lists provides the traceability into the disposition of each project requirement. It also gives management the ability to synchronize new product releases to the market according to a schedule they would like to do so as well as maintaining product development activities are conducted at manageable levels.

Organizationally, Company A is attempting to improve its practices. One area that is not certain is the nature of the teams developing solutions for requirements. The company has an Executive Information System that provides holistic information to management, but is not yet available to most employees. Having one organization responsible for its maintenance and upkeep is important.

Company B

Company B is a large Manufacturing/component-assembly Company in the USA. Its products are widely regarded throughout the world and enjoy a substantial market share in the industry. It is focused very intently on the Voice of its Customers. As these customers can be very demanding, the company spends a great deal of its time and resources ensuring it understands the needs, wants, and desires of each customer. This focus has notably influenced the product development process of this company.

The company has a small percentage of its overall workforce involved in Product Development. Nevertheless, the development of new products and further development of the company's existing products is an important part of the company's operations and many resources are dedicated to this purpose.

Rather than refer to 'Requirements', the company prefers to call them 'Criteria'. The company found from past experience that using the term 'Requirements' introduced rigidity into their processes. Requirements tended to be very specific and changing them to reflect their customer's latest desires and requests were very painful. 'Criteria' evoked a different sort of response within their development community. A criterion is seen as a goal to be achieved, and also one that can be traded against other criteria in a way that defuses loyalty and the politics associated with a 'Requirement'.

The front-end product development process of this company is a convergence of two activities, the formal product development process, and the company's strategic process, that forms a virtual organization charged to investigate a new product development opportunity.

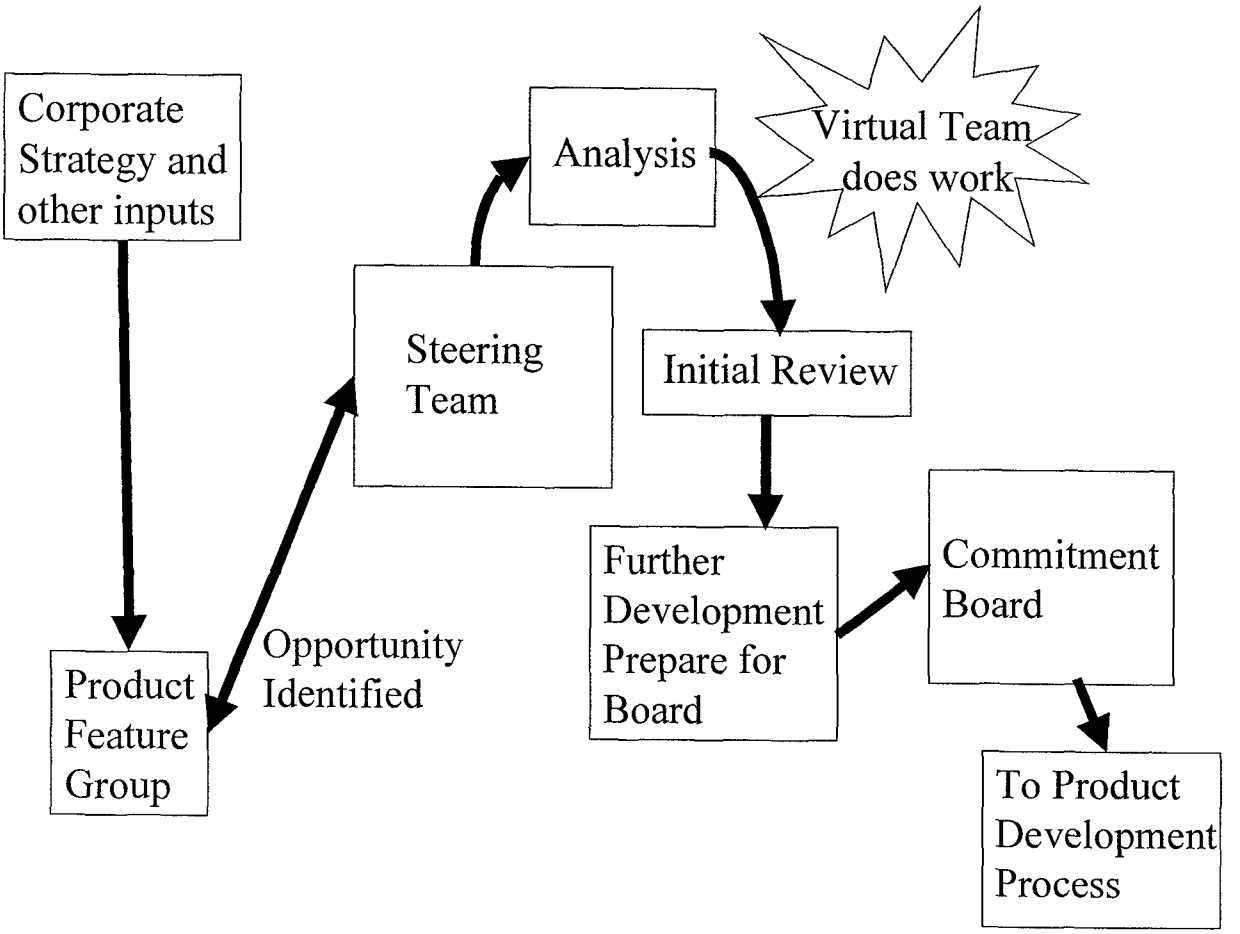


Figure 25. Company B's Front-end Process

The Product Strategy group, part of the Product Development organization, spends its time reviewing the company strategic plan and the current market conditions for opportunities. Specifically, since their company produces platforms, they try to find gaps in the marketplace the company can then exploit.

The company strategic plan has a 20-year forecast. It consists of short-term and long-term plans and forecasts. The focus of the plan is on the first ten years and looks at high-level items like technology, environment concerns, etc. The first 2 to 5 years of the plan are more specific, but are known for huge fluctuations from iteration to the next iteration. The very detailed plan only forecasts the next 3 months. These are updated constantly the time to reflect the most current conditions. The company releases the 'official strategic plan' annually.

As gaps are 'found', a product development or product strategy study is done. A Steering Team starts the study. The team is made up of several lower level managers within the product development organization of the company. When a study is started, a team is organized or formed, taking some managers (with marketing experience & understanding) and 10 to 15 engineers and others from different disciplines. They act as integrators of information and call upon various organizations (internal and external to the company) for the required information and resources that would be needed for future development. This is not a 'separate' team or organization, hence it is more virtual than real. Another reason these teams are virtual is due to the time spent on the study. Study Times ranging from 1 day to more than 3 months (in calendar time) are not uncommon. However, some studies are considered important enough that a dedicated team is formed.

Sometimes studies are formed at the direction of corporate management or based upon customer feedback gathered by the formal product development process. The Steering team manages all these.

The Steering team will also approve the study results and then determine whether to table the effort or decide that it has potential to go forward. The team meets weekly and reviews the progress of each study and/or team. If a decision is made to go forward, the idea or item that generated the study is further developed to go before the 'Commitment Board'. Much more time and effort is made to develop the idea at this point. Budgets of several thousand dollars are not unusual for this further development stage. The board is very busy and it takes about a month to get on the calendar of this board. The package that is then presented to the board includes market-driven numbers that address costs, revenue stream, ROI, etc., and generally supports the idea in addition to the technical information previously gathered during the previously mentioned study. ROI has generally been the real differentiator at this board. The board is the corporate forum to determine which projects will receive funding. Membership of this board consists of the company department vice presidents. Approval of an idea by this forum is considered to be the first part of the business case decision for the project. The total resources required are allocated for the project (as long as it continues to meet development goals in the future).

If the board approves the idea, marketing takes over and begins to 'sell' the idea to its customers. Marketing will develop campaigns for each customer they have. Marketing tries to put the selling points of this new idea into the customer's terms and aggressively market the idea. The customer team

(explained in depth in following paragraphs) is responsible for selling the idea. During the process of selling the idea, the customers' reactions and comments are recorded. Marketing tries to understand what it would take or what capability would be required in this new product for this customer to be interested. Sometimes customer's responses will trigger the launch of another product development study. The recorded information from the customer becomes part of the input to the formal product development process.

The narrative above described only the process required for marketing to win approval to aggressively market a new product concept to its customers. The following paragraphs detail how a concept is developed and a business case for the concept is built using the input, feedback, and sometimes participation of its customers, in addition to the marketing department inputs.

To develop a comprehensive set of prioritized criteria (requirements) the company uses a formal process. This process has four main activities – Identify Needs, Translate them to common language, Integrate various sets of requirements, and Distribute the criteria (requirements) throughout the organization. Each of these activities has several sub-processes or tasks.

'Identify' has four tasks: Plan, Collect, Organize, and Concur.

'Translate' has two tasks: Convert, and Assimilate.

'Integrate' has three tasks: Consolidate, Synthesize, and Rank.

'Distribute' has two tasks: Classify, and Distribute.

The company believes this process acknowledges the different types of inputs into a requirements system or process. This acknowledgement of the various inputs, they believe, is critical to the success of their process. It avoids surprises and pitfalls that otherwise might occur.

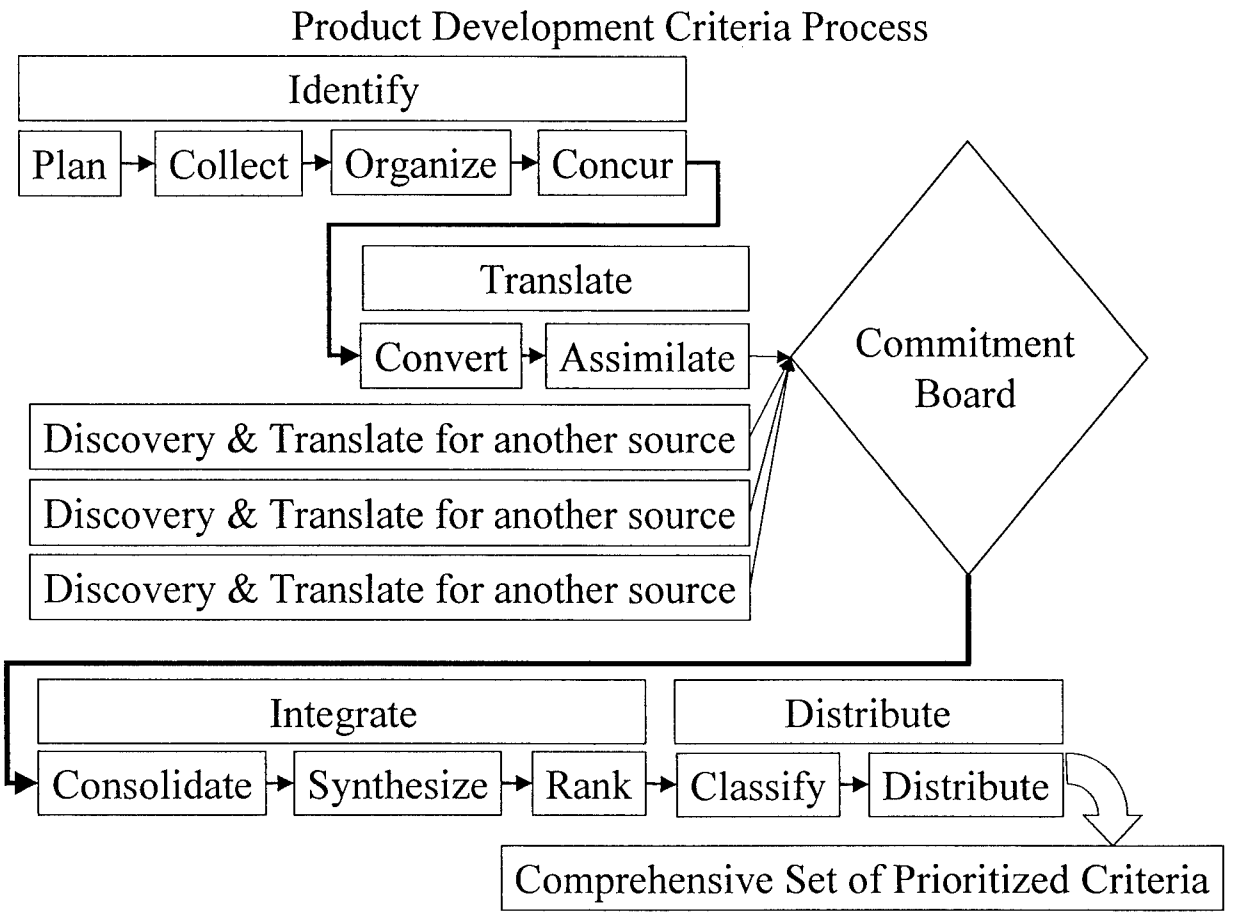


Figure 26. Company B's Front-end Process Flow

Although the material will be treated in a serial fashion, the Identify and Translation processes are multiplied according to the number of input sources they have generally and not just for a particular project. During the 'Integrate' phase these parallel processes will converge into one process flow. To further illustrate the complexity of the product development process of this company, at any given time there may be multiple product development processes running for many projects in development.

Each of the individual input sources go through the Process's Identify and Translation processes. The results are separate criteria lists for each constituency or input source. Some of the inputs are Market Needs, Regulatory criteria, Facility criteria, User needs, Manufacturer's knowledge and experience, Supplier criteria, and Future criteria. The synthesis of these various inputs yields the 'comprehensive set of prioritized criteria'. The Comprehensive Set of Prioritized Criteria contains two types of criteria:

Mandatory and Prioritized. Mandatory Criteria are needs that must be satisfied. Prioritized criteria are "prioritized needs that must be optimally satisfied such that they do not negatively impact mandatory or higher prioritized criteria." There are five attributes to each criterion: traceability to the source; specifications (single, multiple); importance rating; rationale, assumptions; and a verification plan.

The 'Plan' task generates a list of questions specifically tailored for the input source - "What do you want? What are your needs? How would such and such capability influence your satisfaction with our products?" This is done by striving for six objectives: preparing a list of company needs and their associated questions to be asked of the customer; identifying the contact objective; identifying the customer and company personnel; investigating previous contacts - ensuring a single company image; preparing the documentation; and determining the contact logistics.

'Collect' is the collection of the needs AND the assignment of an importance rating to each listed criteria from the input source. There are four objectives in this task. The company wishes to: explain the process; provide current product information; document customer needs; and solicit relative importance rankings. The importance rankings consists of the following: a measure of the significance of each need/criteria; assigned by the need/criteria source; applied to the subject, not the value; and uses a five category scale. The scale is listed here:

The Need/criteria is undesirable.

The Need/criteria is not important, but I would not mind having it.

The Need/criteria would be nice to have, but it is not necessary.

The Need/criteria is highly desirable.

The Need/criteria is critical to have.

'Organize' requires building a database of the information collected so far using a standard template. This forces those collecting the information to document early within the process the information they have received. There are three objectives in this task: Separate the different inputs; document the customer's needs and the company's understanding into a database system; and document, resolve and track action items.

According to the company, the critical part of the process is in the next task, 'Concur'. This is when the information gathered is presented back to the input source and each individual 'criteria' is reviewed. It has three objectives: present the company's understanding; ensure a single voice from the customer; and obtain and document concurrence.

The first three tasks in this process are always in motion. Any member of the company's marketing team, engineering staff, and anyone else that might have interaction with the customer may input information into the process, following the standardized templates. The task of meeting again with the customer to concur happens at regular intervals.

Once the customer has agreed with the information presented to the customer, the activity of 'Translate' begins. The first task in this activity 'converts' the information into 'design language (target values)'. This task, 'Convert', has four objectives: obtain the format required; convert the need into an item which is understandable, measurable and actionable by downstream processes; document the conversion methodology; and review with the customer, as required.

Oftentimes, that which is understandable, measurable and actionable, is what most people would term a requirement. This company calls 'a precise, measurable description of what the product has to do to satisfy the need/criteria a 'target value'.' The target value is based on customer and other criteria source needs; company objectives and constraints; and competitor's capabilities. These are sometimes stated as goals over and beyond a minimum value based on wanting to offer a better product or to be more competitive. They may be single or multiple values; a range of values; or an inequality. Generally, these are labeled with the appropriate units (i.e. minutes, kilograms, etc.)

The second task of this activity, 'Assimilate', extracts the different criteria into market needs and also identifies/quantifies the variations in the different criteria. This task has six objectives: ensure consistency of the converted needs; identify the relationship between the needs; evaluate the related needs for patterns or trends; create the customer market need; document the assimilation methodology; and review with the customer, as required.

A key milestone is reached upon completion of the 'assimilate' task. At this point, management must decide the future direction of the process. They can allow the process to proceed into the next phases or to end the effort or even redirect it. This decision point is the second one made by the senior

management board in regards to nature of the product. It is the same board that approved an initial investigation into the product concept (the initial business case decision). The decision is made with the different 'discovery and translate' processes coming together in one forum to present a 'holistic' view of an entire project in a series of separate presentations. Approval to proceed constitutes a validation of the original Business Case decision. At this point, the company resources committed to the project are reevaluated and adjustments are made as necessary. (Furthermore, marketing and contracts will begin to seek customer commitment to the purchase of this product. This can actually occur at the first business case decision as well (and might be required in order for the project to even enter the formal product development process), particularly with new product lines or platform introductions by this company.)

Additionally, direction might be given by the board to conduct trade studies on different criteria (requirements) and their solutions. These can be new criteria, as uncovered during the discovery and translation processes, or can be on derivations of a 'baseline' criterion set. These trade studies then follow the previously outlined process.

The rest of this case study contains a description of their regular product development process. The description is included because of the activities that occur here while in other company's processes these activities might be conducted in the front-end. Upon completion of the Assimilate task and the decision by the board to proceed, each of the separate input sources' wants and needs should be clearly known.

The next activity, 'Integrate', takes all of these criteria and 'integrates' them into a common list. The task of 'Consolidate' is a compilation of all of the collected criteria. This task has four objectives: combine the information from all sources; identify the relationships between the customer needs and the other criteria; categorize the criteria; and identify the hierarchical relationships between the criteria. The task 'Synthesize' has different objectives. There are four of them: identify patterns or trends within each category; derive the single criteria within each category; resolve conflicts between criteria; and document the synthesis's rationale. The last task of this activity is 'Rank'. Here, factors are applied which account for the company's goals and objectives, according to the following areas: product strategy; business strategy; timing; customer delight; competition; technical characteristics; and technology level, etc. The task has three main objectives: evaluate how well the criteria satisfy the

'influencing considerations' or factors; document the rationale; and use expert judgement to sequence the criteria list. The analysis is accomplished by judging how well the criteria addresses the influencing consideration questions, by using the following 5 to 1 scale: 5=Very Strong or Yes; 4=Strong; 3=Medium; 2=Weak; 1=Very Weak or No.

The last activity, Distribute, is focused on getting this information to the right places within the company. The first task of the activity, 'Classify', separates the 'Must Do' criteria from those that are tradable, or the mandatory from the prioritized ones. This is another screening point for the various criteria. The next task, although it does not affect the criteria in any way, is still the responsibility of the product development organization. This task is to 'distribute' the information and has four main objectives: identify which process(es) should receive the information; create the appropriate format; distribute the information; monitor and control the integrity and quality of the information; and measure customer satisfaction.

The entire process, although it is iterative, usually takes 3 to 6 months, depending upon the complexity of the project. The company judges the overall process on two merits: how well the customer is satisfied and how quickly the process is navigated.

Once the criteria have been fully developed and finalized, the product development process does not end. The criteria must be then translated into detailed design decisions. This is the 'Process of Product Configuration Definition'. This seeks to develop the criteria further in both breadth and depth. Since the output of the initial process in the front-end is a definition of the criteria at the product level (system requirements level), the next step is to define the high-level functional elements of the product. This is followed by the high level definition of the physical elements of the product. This development continues in an iterative process beginning with the product itself and then working down into more detail at the system/subsystem level and then finally at the component level. Again, each of these goes through a functional definition and then a physical element definition as part of the 'Process of Product Configuration Definition'.

During this time, it is likely that some customers may provide additional input to the process. Therefore, the company has developed an exhaustive method for managing customer requirements. It is an approach and strategy of mass customization. This approach maximizes reusability of

engineering and manufacturing data, while allowing customers to tailor a product to their satisfaction. First, as much as possible is developed by designers that are essential basics and will remain stable for the product (a no-frills version of the product). Second, many optional features are designed up-front, but the added costs (including development costs) for these options are passed directly on to the customer choosing that particular option. Finally, customer-unique options/requests absorb the full cost of development, engineering and manufacturing operations for that option. A unique feature or option request is the most expensive option for a customer to choose. This strategy allows the company to keep the unit costs of its products low rather than forcing all of its customers to pay development costs for features that are only required/requested by a few customers. In some sense this is a product customization strategy or a product line differentiation strategy.

Organizational Issues

The company uses 'customer teams' in the product development process. These teams are made-up of individuals from Customer Engineering, Marketing, Customer Services (support), Sales, Customer Relations, Marketing Management, and Contracts. These teams are most often focused during the Discover stage of the product development process and also the most stable. In some cases, these teams 'know' their customers and how they are using the company's products better than their customers do. As the process progresses into the downstream stages, the composition of the 'team' that develops the requirement changes (it is a new product development team), but the product development team still maintains links with the customer team to ensure the correct feedback (i.e. sanity checks) occurs with the customer.

The organizational group that controls the product development process is multi-disciplinary. This organization could not entirely absorb marketing, service, support, supplies, etc., but the organization brought in numerous representatives from these other organizations to ensure the broadest multi-disciplinary, cross-functional base possible for the development of products for the company.

By design, the process tries to be simple. The Product Development Organization believes it must be kept so, otherwise, manufacturing as well as product design engineers will 'get ahead' of the process. As the 'clockspeed' of this industry increases because of the shortening technology development cycles, Product Development is constantly seeking ways to improve the product development process and keep its cycle time low.

From an organizational standpoint, this company has endured some painful adjustments. It has recently completed an organizational shuffle that drastically altered the way the company was organized. It was implemented in January 1999. In some respects, this change recognized the product development process that had evolved over the years, and now aligned the organizations properly. Previously, the company had been entirely organized around functional departments and also product teams. Duplication of effort and waste of resources, not to mention customer dissatisfaction were reasons for the reorganization. The new organization brought portions of Marketing within the Product Strategy & Development organization of the company. These portions were those of marketing that concerned themselves with marketing specific products and customer requirements as well as strategy planners for their products and features. This new organization was designed to eliminate the multiple company representatives that would call on customers. One customer once complained, "You're the seventh person I've talked to and I've yet to see this resolved."

The other major change was the dissolution of product organizations and realignment into platform organizations. The hope was to avoid the costly duplication of different designs for common elements of their products. For instance, two product elements currently exist that have the exact same dimensions as well as the same requirements for performance. From an appearance standpoint, they are not distinguishable from one another. In terms of performance, these products perform identical tasks. Yet, these product elements are manufactured differently and are not interchangeable with one another.

Business Issues

There are approximately 20 people in the management group of the product development process of the company. These people come from the corporate levels of the company and control the process. They exercise control over the process by having lots of reviews and management oversight.

Resources for the product development process come from the different product lines of the company. The share of resources product development gets depends upon how well the product is doing in the market. This fact tends to influence product development to 'heed' its larger benefactors more than other product lines that don't contribute a lot of resource to the process. In the case of a new product line launch, the resources come from overall corporate resources.

The company has been using a common IT solution for their 'criteria' (requirements), their development, and translation into technical specification (DOORS). Traceability is of primary importance - all the way back to the customer source. They currently have plans to deploy this tool (or a module of it) into the hands of their customers as soon as they can ensure the security of each customer's data.

Furthermore, they are moving from 400+ computing systems to one networked computer system, responsible for the creation of a single bill of materials vs. hundreds of them. This computing system is for all company scheduling, ordering, purchasing, and production of its products. The outcome will be reduced product production flow times.

Summary

Company B has a formal product development process. Only in the past year has the front-end process been integrated into the same organizational structure as their formal product development process. Because of this, it is not yet certain how effective company B has been in its recent efforts.

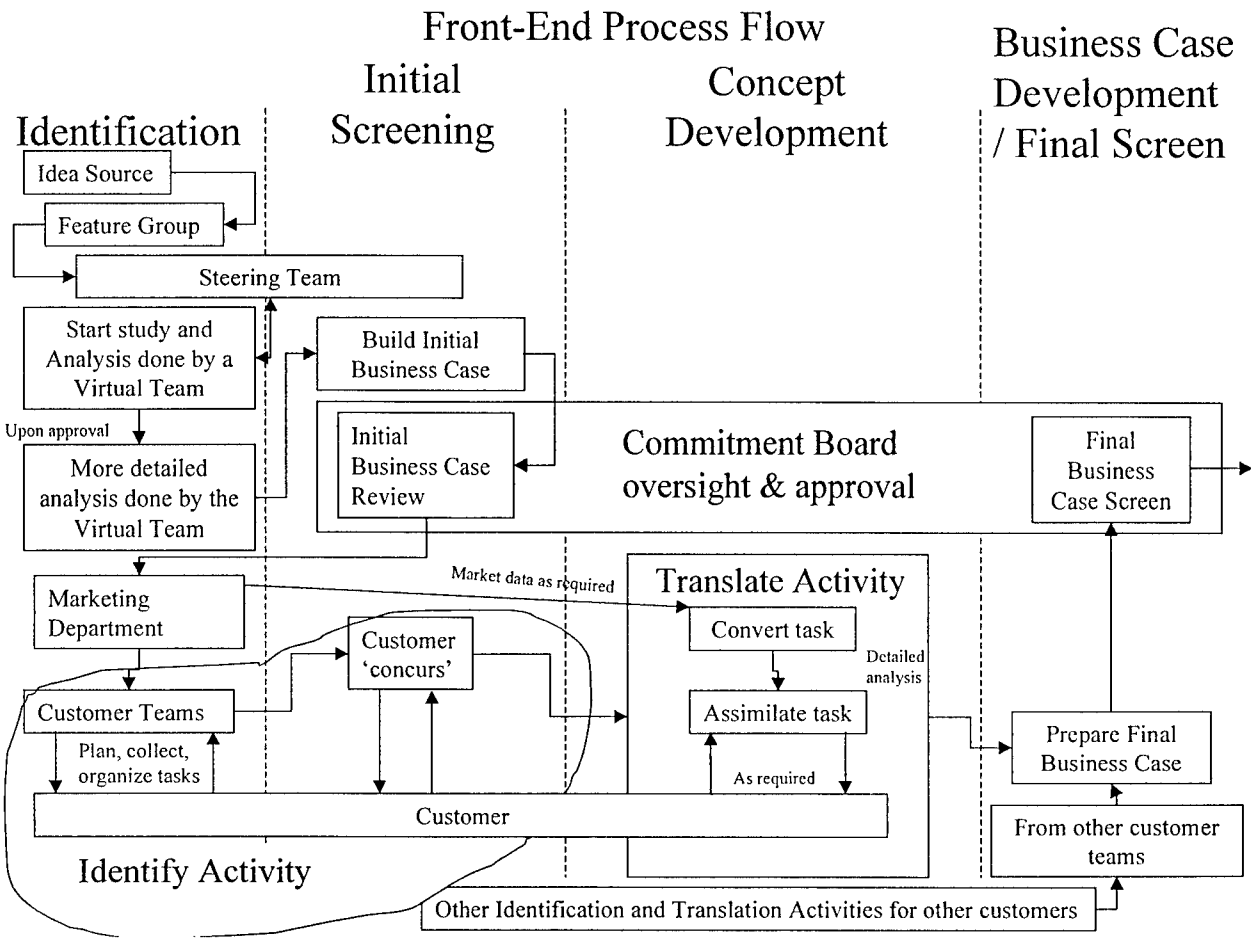


Figure 27. Company B's Front-end Process in Terms of the Framework

Overall, the design and operation of company B's process mirrors the process framework presented earlier. Unique elements are those that reflect the overall position of the company's close ties with their customers. The additional review gate for the business case between in the front end and the first review gate in the product development process seems to be a risk mitigating approach. This would be especially true for new product lines where the development costs are huge. It appears the efforts done during the front-end are to develop and gain the confidence of the company's engineers and technicians. The final business case preparation period seems to be conducted to convince their customers that the company is up to the technical challenges and also to include them in the exploration process of the opportunity space.

Company C

Company C is a materials science company that is in the defense, telecomm, and consumer electronics industry as a maker of a broad range of high performance accessory products. It has its headquarters on the West Coast of the United States. The description of the process used in the front-end development of new projects is based upon activity prior to its recent acquisition by another company.

The following graphic depicts the process. The detailed explanation of the overall process is found below.

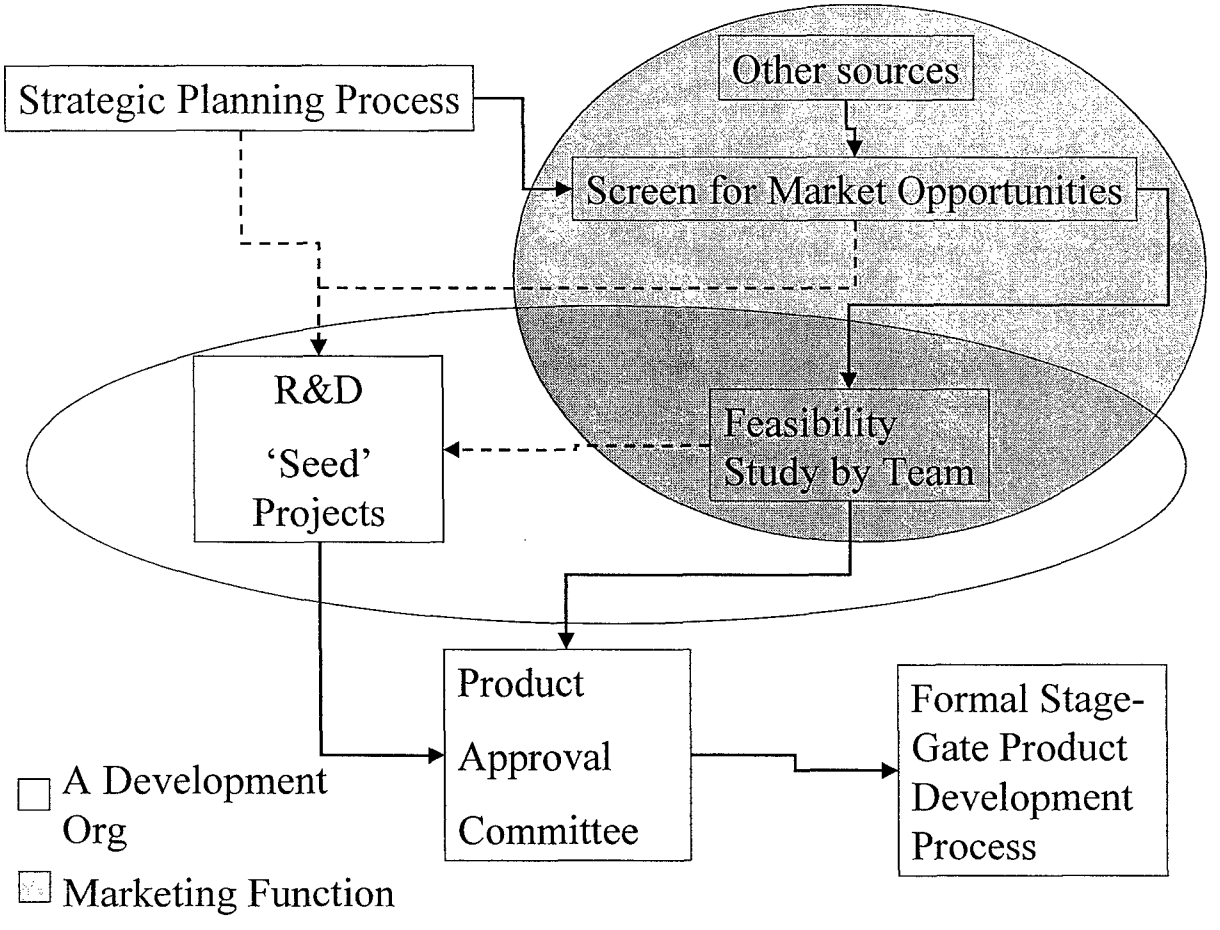


Figure 28. Company C Front-end Process

The company uses several processes to get New Product Development Projects going. The first piece of the process is the strategic plan of the company. Part of that plan specifically addresses areas for

growth (new markets, existing markets - existing customers, existing markets - new customers). The strategic plan has a horizon of five years and is done annually. March 1 is the beginning of the planning cycle and July 1 is the start of the fiscal year. All planning must be done prior to July 1.

The second piece of the process is the company's use of a business operations plan. It has a two-year horizon. Oftentimes, it is really just a one-year plan. The plan is created annually (with 2 years worth of projections), but is revised often between the formal revisions. This plan is used to actually disperse money according to the company's business objectives. It seeks to implement the vision and goals of strategic plan in a realistic manner.

The marketing department actively scrutinizes the strategic plan of the company. A market team will examine the market and try to flush out opportunities that are in harmony with the overall strategic plan. As opportunities arise, marketing will approach one of the development organizations within the company (that is likely most aligned with the new opportunity or idea), and solicit its support (money and personnel) to evaluate the opportunity. This is the feasibility evaluation. It is done for every new idea or product opportunity. A team of individuals does this, a marketing/sales person and a minimum of at least one technical person. It is not uncommon for these teams to contain only two members. Once established, these teams remain in place until the feasibility study results in an approved project or is terminated. The personnel on the teams rarely change, rather, they gain experience working together on different feasibility evaluations.

The reports summarizing these studies are only 2 to 3 pages long. Several criteria are used to prepare the evaluation and will be the same ones used during the project evaluation. These are: the clarity of the opportunity; the reasons to begin the project now; how it addresses the skills and strengths of the firm; the opportunity that exists in the market; the complexity of the project; and how long it will take to complete development. The answers to these criteria build the business case of the project. Some of the outputs of the study include a 5 year income statement projection, NPV, IRR, Cash flows, etc.

The costs for these studies are usually absorbed by one of the development organizations in the company. However, occasionally another organization will pay, as the cost of such studies is generally not high. Unfortunately, sources of funding are not always secure or guaranteed. Typically, the issue revolves around which organization should pay for the evaluation vs. the expected return of the

evaluation. Despite this, attractive opportunities always seem to get funded through the feasibility stage.

A Product Approval Committee reviews the business case of each feasibility evaluation. The general manager of each division sits on this committee. It meets on a regular basis, typically once a month. In these reviews, projects are killed if there is a compelling reason to do so, like one of the previously mentioned criteria being completely out of acceptable ranges, particularly the financial estimates. Approval of a study sends the project into the familiar stage-gate process widely in industry use. The design review process is separate and deals with more of the technical details and is conducted as part of their stage-gate product development process.

The stage-gate process is very typical for their development products. A distinguishing feature of their process adds criteria to the previously explained list of criteria at each subsequent gate. The project's performance is compared from gate to gate, stage to stage. The figures in the original study are always revisited and revised at each gate.

Organizational Issues

The Product Approval Committee has also developed a rule of thumb or a heuristic for its use. After a period of time, the committee begins to distinguish the figures coming from individual teams. It has developed from experience the knowledge that some teams are more aggressive than others are, and some teams have 'softer numbers' than others. The Committee takes this into consideration when making decisions.

The teams used to conduct the feasibility evaluations have also developed some rules of thumb. One is to take more time up-front before a potential project goes to the Product Approval Committee. Another is that senior employees with a lot of experience should always manage teams. They must have experience in the area under consideration as well. Junior employees are always part of the team, but do not hold leadership positions. In this way, a form of mentoring takes place within the team.

Business Issues

The overall cycle time from 'gleam in the eye' to the business case decision is only a few months. The average is 3 months with a normal distribution.

The company believes it has a very active front-end. The company expects to see a lot of activity here and lots of projects under evaluation. If there is not a lot of activity here, action will be taken to reinvigorate the front-end. Nevertheless, the different projects are expected to be filtered/funneled out as they move along the new product development process. So, they track the number of projects at each stage of development vs. a historical trend for each stage. Goodness is measured by a decreasing number of active projects the further into the product development process the project is.

Another metric is the numbers of ideas undergoing exploration vs. those that are already in the process. It is related to the metric described above, but specifically focuses on the 'robustness' of the front-end. Simple graphing of this metric can serve as a visual indicator for the company's decision-makers. Very quickly, the company can ascertain its NPD health by knowing what things are in the 'pipeline' or about to enter it.

The last metric of note is the tracking of 'seed' activities. These are projects that currently don't fit into the corporate vision of the company nor have a commercial vehicle to take it to market. However, the ideas are interesting with tangible commercial possibilities and potentially could develop into a project. A small amount of seed money is set aside to further explore these ideas. Additionally, these 'seed' activities are not likely to be completed within the typical 3-month process cycle time. When the activity is complete, the Product Approval Committee makes a decision whether or not to pursue it further using the regular process.

Summary

This company's process incorporates many of the features of the ideal process outlined in the framework. Some of the unique features of this company's process are the metrics outlined above. Additionally, the recognition of the feasibility teams' personalities and work and how it impacts the review of their work by the Product Approval Committee is noteworthy.

The relationship between this company's front-end process and the idealized framework are highlighted below.

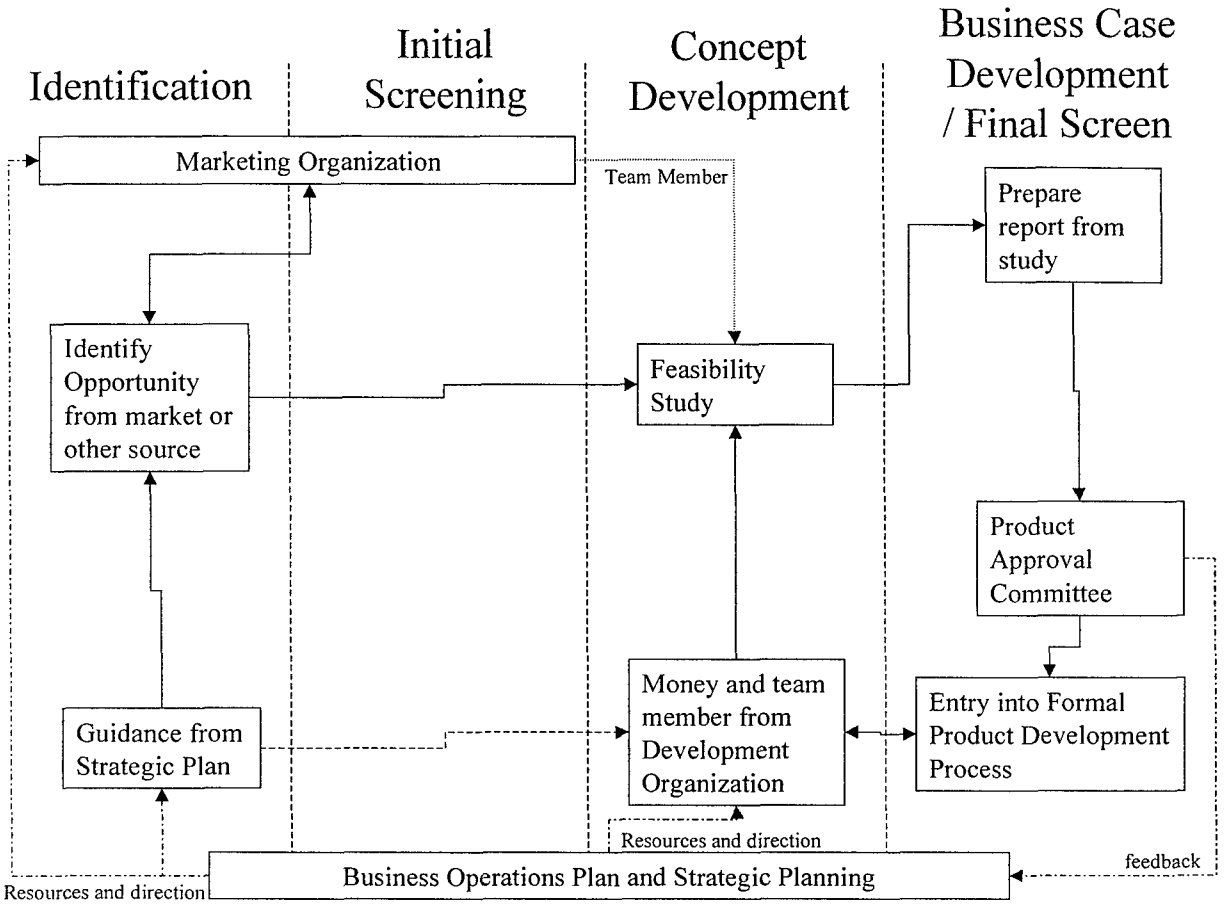


Figure 29. Company C's Front-end in Terms of the Framework

The company has only one formal screen done by its product approval committee. There is no corollary to the screening stage of the framework, however, the activities that occur during that time, according to the process maturity matrix, are spread through the other three framework activities within the company's process.

The company's process contains areas of concern, particularly the potential for 'in-fighting' within development organizations regarding the funding of these up-front studies. Another area of concern is the organizational relationship between finding 'market opportunities', conducting the feasibility study, and the regular product development process. Potentially there are three different organizations involved in the entire process. The last area of concern is the lack of continuity between the work done by the team during the feasibility evaluation and its transition to a new product development

team in the regular product development process. However, this is generally a non-issue as the feasibility team typically becomes the nucleus of the product development team.

Company D

Company D is a computer software company providing solutions for business and personal use. It is a subsidiary of a Fortune 100 company. It is headquartered in the USA.

Company D's process at a glance is not as structured as other firms' processes. A select few individuals make most of the decisions, and these are done based upon a business case. However, their process is one that they believe will allow them to compete most effectively in their market space.

The following diagram and following description explains their process.

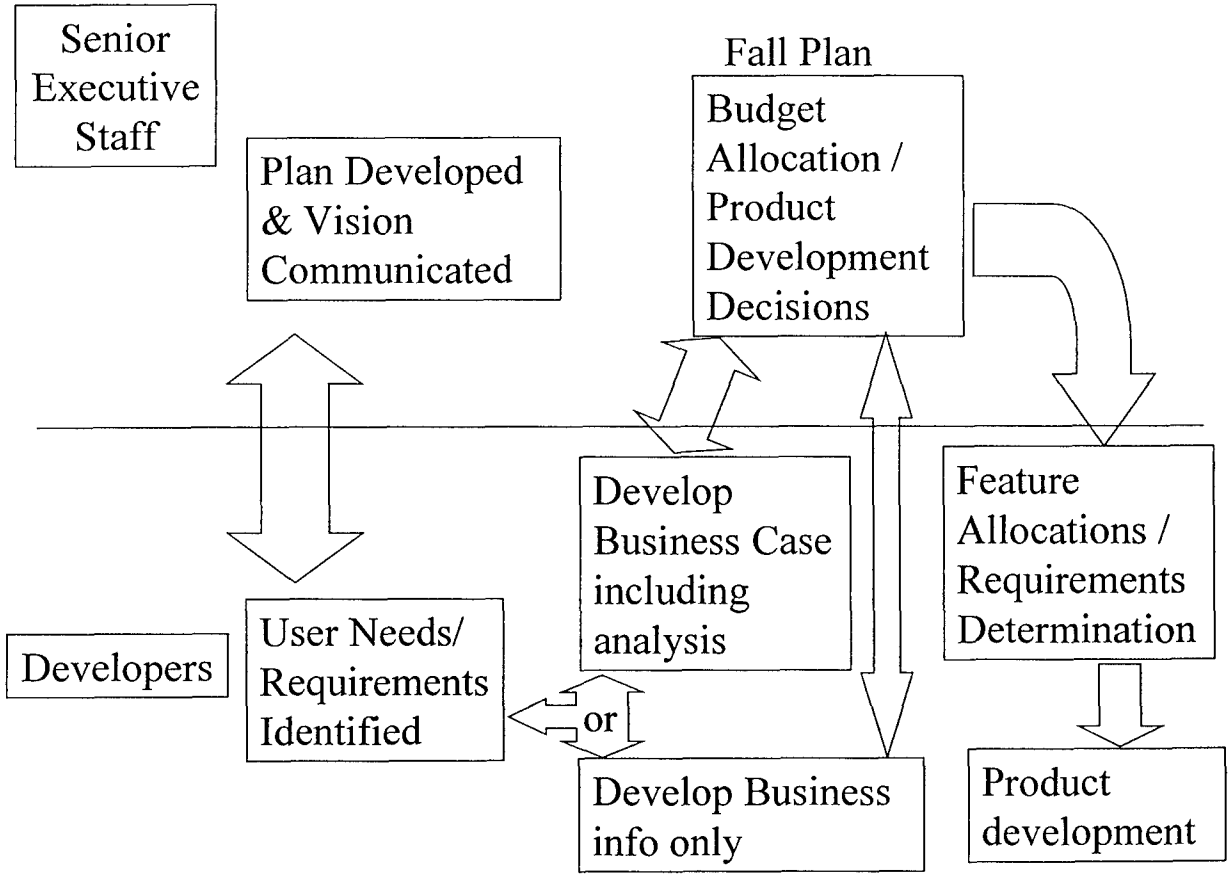


Figure 30. Company D's Front-end Process

A Senior Executive Staff, consisting of all of the vice presidents of the company and the company's product managers, once a year determines 'strategic' directions for the company and then 'tactical' decisions are made at lower levels. Examples of 'strategic' decisions include the approval of new product development activities and vision statements. Examples of 'tactical' decisions are working upon product upgrades and feature improvements, customer support and which features to pursue.

The developer of a business case is usually one person. According to the company, 80% of the company's ideas for both new products and features come from the bottom-up (a software programmer). These plans are put together by people at the lowest level. Another 18% are specific inputs from their customers and again are fielded by lower-level employees. Only about 1% come from the executive level and are pushed on down. Therefore, practically all product development activities come from the lower-level employee and is also the most likely to build the business case.

Most business plans are developed within 4 weeks by the originator or the employee that fielded the specific input from the company's customer. This includes analyzing the data, putting together the report, coming up with their recommendations, and choosing the best alternative. No formal team is put together, but employees often seek each other for help with various aspects of the business plan on an as needed basis. (A new employee would seek help often and a more experienced one would likely not need to do so.) With partners outside of the company, these plans can take longer, but no more than 7 months. If a radical innovative plan is being put together, it would take anywhere from 7 to 9 months.

The business case is built upon a lot of analysis. This is because decisions about the business plans are based upon several standard criteria: cost (of development), the time to market (the cost of delay), and the revenue potential. The money required vs. revenue potential is the biggest factor in the process.

Lastly, if there is a new opportunity identified, and it is in an area the company is well established and has a lot of experience in that market-space, the supervisor of the employee will direct the employee developing the idea to not do a full business plan with analysis. Instead, a simple business case with just the overall information about the potential returns and development cost is used and is all that is needed. Entirely new business, however, must go through the rigor of the up-front analysis.

When a business plan is being debated, the process lasts 2 to 3 weeks. Most of the discussion done at the Senior Executive level is about the validity of the data. They do not debate the product features; they feel it is best left at the lowest levels of the company.

The actual plan of developing the new product is much different than the business plan. They feel that otherwise the effort would become compromised. Furthermore, if one of the several development organizations is unable to develop a new product according to cost and schedule constraints, the company will threaten (and has done so) and actually move the development to another organization. Their belief is that they should treat their developing organizations much as a customer of theirs would treat the company if it were not performing. The result of this external threat is that there is little requirements creep or growth beyond the initial approved set at the outset of a project.

Organizational Issues

In this process, decision making is pushed down as far as possible - to supervisors of software programmers. This empowers the lower level of the organization to work within generally defined spaces, but to pursue opportunities perhaps unforeseen at higher levels. The organization reinforces the concept that the developers really understand the user needs and requirements much better than an executive staff. The staff merely decides if the potential returns and overall commitment of company resources is in harmony with the overall vision and outlook of the company.

Also, decisions to pursue opportunities for new products or other product enhancements are made at the lowest level. The programmer that wishes to pursue this opportunity determines with the help of a supervisor whether or not it fits the criteria of 'being within one of the company's well-established market spaces'. Regardless of the approach used, the proper business 'numbers' (return and investment costs) have to be provided to the company's leadership so they can make a final decision.

It appears that partnering with other organizations increases the complexity of the process. Perhaps this is a reflection of the consensus-building/networking/advocacy environment present in this process. A process that normally takes 1 month to complete may now take up to 7 months. Additionally, major new product development projects (with new software architectures or reusing existing platforms) seem to force tremendous turmoil into the process because of all of the different

interactions with other projects and company products. In such cases, the overall process may require 7 to 9 months.

Business Issues

The process to make business decisions for New Product development has a cycle time of about 6 weeks. This happens in an industry where, according to company information, product development cycles last 12 months and product lifecycles are about 3 years. Total overall cycle time is 3 ½ years - from idea to retirement of the product.

This company has a Spring and Fall Plan as part of the company's budgeting and strategic planning process. The Spring Plan is a two-year outlook and contains broad strategic objectives. This plan is actually put together by the parent company. Money is allocated according to this plan in broad generalities (i.e. existing project groups, planned new product development projects, and management reserve).

The company's fiscal year begins on July 1 of each year. However, the company operates (and spends money) on a calendar to calendar year basis. The Fall Plan explains this strategy. During the build of the Fall Plan, 3 to 5 days are needed to determine where the money will go. Other business opportunities are identified at this time as well. This point in the process is where the new product development ideas receive funding.

Additionally, new product development ideas with accompanying business cases can come up at any time of the year. When this happens, the fall plan is flexible enough that according to the judgement of the Senior Executive Staff, money can be reallocated. According to the company, failure to have this kind of flexibility in the changing market they are in can mean the difference between succeeding as a company or being forced out of the business.

Summary

Company D believes its survival and competitive advantage comes from the unstructured nature of its front-end and from the relative autonomy granted the individual employees. In comparison with the framework, as the diagram below attempts to illustrate, these ideas have the biggest impact on the company's process and are the sources of the main points of differentiation from the suggested ideal process. The most obvious point of differentiation is during the screening phase when a supervisor

assumes this role. The distinction between this company's process and the framework is that screening decisions are made in light of the entire product development stream. This company's process allows any idea that 'looks good' to go forward. Another impact is the relationship the company has with its parent company and the financial implications of that relationship. The parent company has always used a stage-gate, phased-development product development process. It has expressed dissatisfaction with this company's process and uses every opportunity to scrutinize it. Nevertheless, this company is quick to point out the process used by the parent company is considered unwieldy and that it removes decision power from those who know best (the employees/programmers/users).

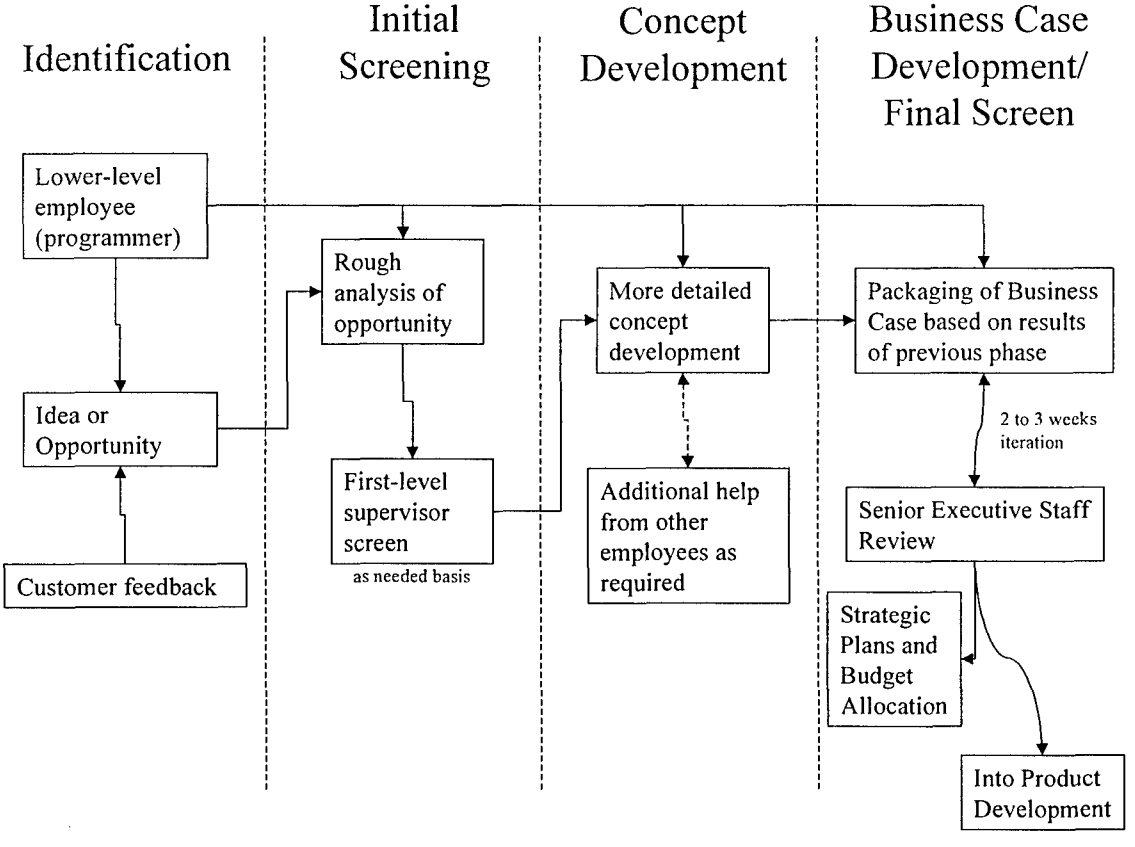


Figure 31. Company D's Front-end Process in Terms of the Framework

The same person or groups of people that originally developed the business case for the idea conduct product development. They do the work required to take the idea from conception to the market.

Organizational issues such as knowledge transfer and requirements creep are possibly minimized because the same individuals are involved in the project from the beginning.

The method by which New Product Ideas are processed introduces the concept of the Process Takt Time. Although the overall process from 'dream' to business case is typically about 6 weeks, new product development projects are usually 'started' (i.e. receive funding) once a year. So, the Takt time of the process is actually one year. Of course, the company has measures in place to begin development work on other projects throughout the year (i.e. a management reserve, flexibility in the Fall Plan, etc.). A further mitigating factor is also the relationship between the company Spring and Fall Plans. Special funding can be received when absolutely necessary through the Spring Plan mechanism with the parent company.

Company E

Company E is a computer manufacturing company that deals with all aspects of the computer. They manufacture their own hardware and software systems. The company is considered one of the major players in the computer industry and has locations throughout the country. The company is organized into several operating divisions or separate business units. The Corporate Headquarters are in the western USA.

There is no formal 'process' of New Product Development for the entire company, although initiatives are underway to develop a common phase release policy and pilot projects are prototyping this approach. However, there is an accepted framework for developing ideas and choosing the engineering solution. From within this accepted framework, the business plan is developed. The framework does not dictate how to navigate the 'informal' process; rather it provides suggested methods to use in developing the business plan. Each operating unit or division is allowed to locally interpret the framework. Oftentimes, according to a company source, the company seems to operate in an ad hoc fashion in regards to new product development decisions.

The following diagram illustrates the general front-end in use by this company.

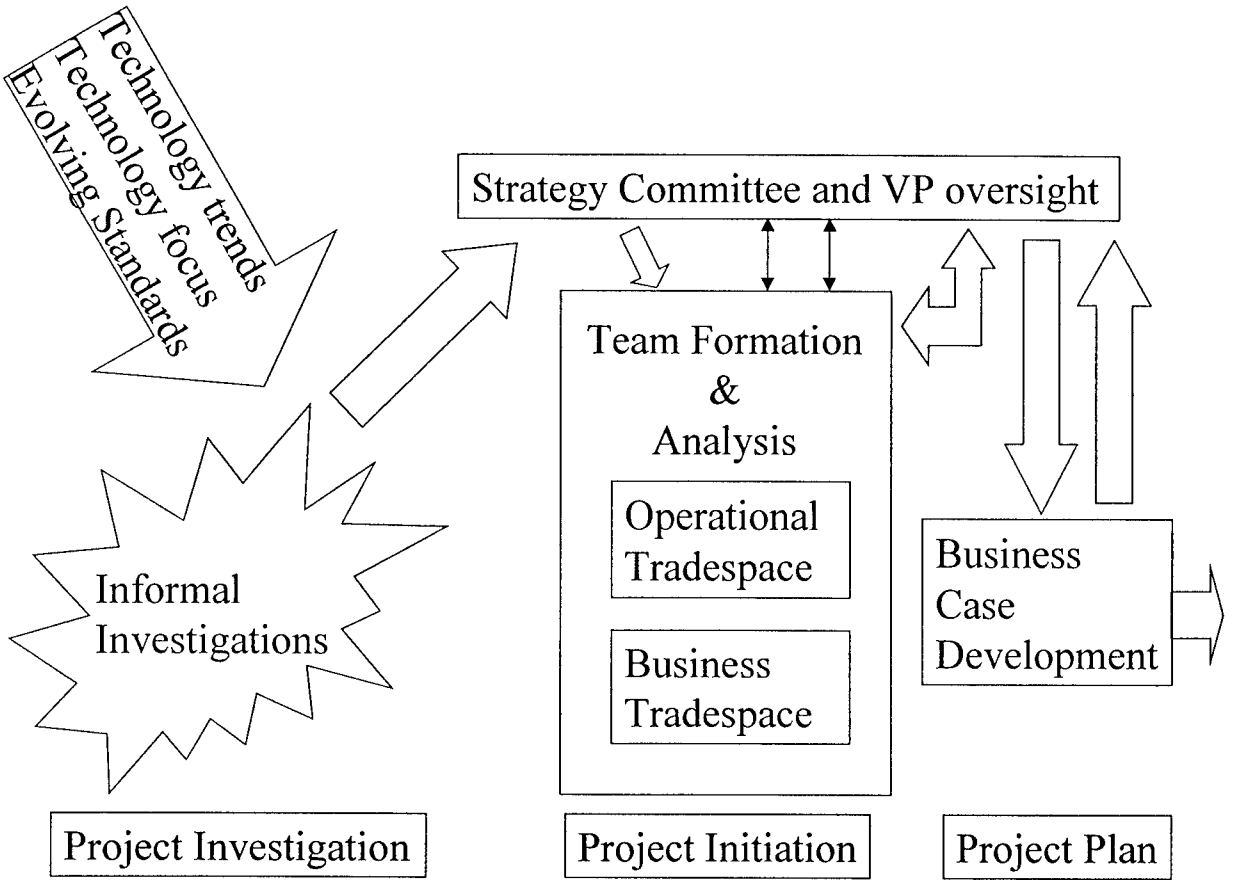


Figure 32. Company E's Front-end Process

The company is driven strategically from three areas: Technology trends (i.e. Moore's Law - doubling of processor speed every 18 months); technology focus (the vision for the company in 3 to 4 years); and evolving standards for computer components (both hardware and software). The key challenge facing this company is a product development cycle that exceeds the market life of the product (i.e., it takes 2-4 years to develop a next generation product which may only have a useful revenue life of 1-2 years). Hence, there is a great deal of uncertainty about the market, competition, standardization and customer throughout the early stages of a product's life. The lack of a formal process is considered an asset by some in allowing flexibility and speed in addressing new information, as it becomes available without rigid rules for dealing with exceptions.

The process leading to the completed business plan consists of three phases: Project Investigation (analysis of technologies and concepts vs. needs); Project Initiation (comes up with a suite of solutions matched to the identified needs); and then the Project Plan (containing the chosen feature set/requirements). In the first two steps, cost is only a guide. In the last step, cost is very important as the entire budget, financial analysis, NPV, etc., is based upon this.

Informally, these steps have other names. The first step is called the "Up-front Process". The second step is the "Generation of Concepts" stage. The last step is the "Project Approval Process". The boundaries between these steps are not well defined and it is difficult to quantify where one ends and one begins. However, the Project Approval Process requires an end document that is rigorous and complete, suitable to act as the contract between the product development team and the corporation.

Sources of ideas for new products are varied. Because of the highly volatile nature of this industry, many ideas come directly from the trends seen in the marketplace. Others come from feedback from customers, and still other sources are those from within the company (R&D and also directly from other employees). There are many more ideas and opinions than resources to chase them, so filtering these inputs are extremely critical.

Ideas explored in the Project Investigation phase are generated in a bottom-up fashion, usually from within the technical ranks. Very few are top-down directed. Each product group within the company is expected to devote small amounts of time as well as resources to developing other ideas without getting approval from upper management. Usually this is in the form of 'spare' time and isn't formally tracked by the company.

As the idea matures, and the idea champion(s) believes there is merit to the idea, funding is sought. This is the beginning of Project Initiation. The champion gathers some rough information about the idea and presents it to a decision-making forum. The decision to pursue this project is made by the division Vice President.

The Vice President of the division or operating group holds weekly strategy meetings. The meeting serves as a heading check on all of the different projects that are underway at any given time, as well as being the approval point for any new projects. The focus is on the revenue/profit potential of any given project. However, the decisions on product requirements and/or product features are left in the

hands of the technical community. Company E manages this process by keeping track of the number of projects in the development process, and not letting too many into development. With approval, formal team formation occurs (or is acknowledged) and the idea is developed further. It is typically at this time when the formal assignment of a program manager occurs.

Additionally, a strategy committee meets on a regular basis to discuss among other items, issues of cost, quality, product availability, time to volume, and the strategic focus of their products. Due to the influence of the strategy meeting, the company has a rolling product priority list. It is updated on a monthly basis.

During the phase of Project Initiation, two different types of analyses are done. These are the 'Operational' and 'Technical' analyses. Operational analyses are more of the market research and business implications. This analysis allows the team to understand the 'business trade space' that exists. The technical analyses focus on more than just the technical implications, they also address the technology space (a trade space offered by using different mixes of technology and engineering) for tradeoffs.

Once these tradeoff spaces have been identified and explored, the last phase of this process begins - the development of the Project Plan. During this time, the formal business case is developed as well as determining the single 'solution' to pursue along with the 'requirements' for that solution.

'Boundary Conditions' are part of the detailed technical requirements that are developed during the business case development. These are areas that are similar to 'must-meet' requirements or 'minimum necessary conditions'. They also are able to indicate goals or those features that would be 'nice to have' within the cost, schedule, and other resource constraints the project has.

The suggested elements of the business plan are the description of the technical proposal; a financial analysis; market and competitive strategy; schedule and resource requirements for the project. The plan is usually about 100 pages long (including the back-up technical pages). They put together an additional 'summary' (about 5 pages long) that is used by the decision-makers for the actual approval of the project. Sometimes projects look very much the same on paper, but in reality are very different. They have a different focus and different application. The team responsible for building the business case must emphasize the differences during the approval process.

Upon the completion of the business case, it is presented to the Vice President of the company division. With approval, the project moves into their product development process. It is a normal practice for the team members to remain together for the rest of the development effort (when they aren't spending their spare time pursuing other potential projects).

The entire front-end process is complete within approximately 2 months. This time frame includes the time spent in starting up the team, getting them assigned to the project, and actually doing the work associated with building the plan.

Organizational Issues

During new product development, the team used to build the business plan is cross-functional and the members can potentially come from any part of the company. The teams tend to be self-selecting, based upon employees' reputation, and knowledge in a particular area. This is another reason why internal networks are important to the individual employee.

Due to the rate of change in the industry, the full appreciation of technological change, engineering capabilities and issues resides in the senior technical staff. Management tends to become technologically obsolete very quickly in this environment. Therefore, Company E favors its technical staff over the opinions of its management staff in terms of product requirements and the product features. Management simply determines the financial merits of the project and decides only to proceed or not. This requires the development of trust in the technical staff and an individual's integrity may often be the deciding factor in whether or not to proceed.

Furthermore, the company will completely reorganize itself every 3 to 4 years. This kind of reorganization can be dramatic. The existing business units are realigned and internal divisions are completely dissolved. New divisions are formed around the more profitable product architectures and employees are often transferred within the new divisions. This is a deliberate strategy to keep the company agile in this industry. This is the way the company reacts to market changes vs. institutionalizing a committee to deal with the changes. It also forces the development of internal networks within individual employees.

Business Issues

The company uses a 3-year planning horizon to guide their corporate strategy. A longer timeline is not realistic given the volatile environment of the industry. The company's Research & Development department uses this horizon to develop a portfolio of potential solutions that then go forward into the other front-end processes, as discussed above.

Another issue deals with new technology. New technologies are rarely adopted outside of the development organization (every department has some kind of internal R&D) unless they have been incorporated into a successful product from that organization. This is recognized as contributing to duplication of effort, proliferation of similar, yet different, products and to extending validation cycles, but also enables very specific targeted products to be developed quickly without a lot of external dependencies.

A final issue is associated with the costs of putting together a business case. The costs are usually absorbed by the developing organization or associated project. The costs associated with the front-end are managed closely by tying expenditures to customer value and perception of their products. As long as the business case development is actively addressing these areas, they are given wide latitude within the original budget. The development costs are used as a guideline. It is typical for the schedule of a project to move fluidly. A great deal of effort is spent at the finance manager level to quickly identify opportunities when a project underspends and reallocate it during a financial quarter. Product/component costs are more rigorously managed due to the greater potential impact on revenue and profit.

Summary

Company E has a process that promotes flexibility. The process is built upon that principle. This feature is evident during the team formation stage, as the team is self-selecting. The self-selection happens according to the capabilities of the individual (via networking through the organization). Additionally, the source of the ideas is bottom-up driven. The culture of the organization favors the ideas of the technical employees over those of management. This attitude could lead to performance-driven products and features, but the company allows management to make the project decisions on the financial returns in the business case. The development teams are held accountable by management to stay within the development budget requested as part of the business case.

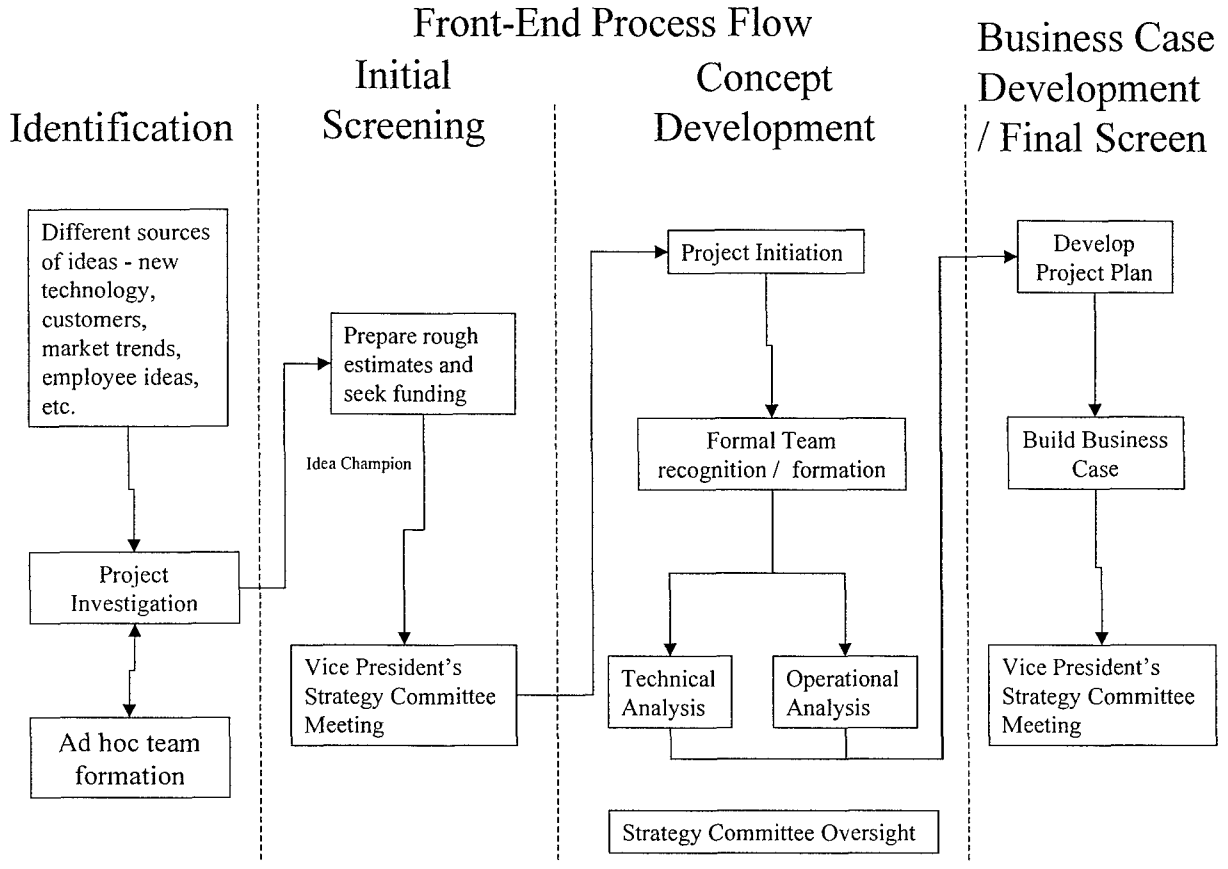


Figure 33. Company E's Front-end Process in Terms of the Framework

Despite claims by the company that it lacks a formal process, a process with many elements similar to the framework described earlier is present.

To its credit, the company has one organization that develops the idea. However, there is the potential for new products to be created in a vacuum between the different business units of the company. The company's strategy to mitigate this possibility is achieved through the design of the company's business units. They are divided in a way so that they operate in an exclusive 'area' within their corporate framework. This means that certain types of hardware and/or software are only being developed by one organization of the company. Should too much overlap occur, this is a sign to the management of the company that it is once again the right time for the company to reorganize. Nevertheless, these separate units must maintain close working relationships with the other business units. Failure to do

so would result in possible interface problems with the products they offer (i.e. software being unable to work on new hardware products and so forth).

Company F

Company F is the product design and development organization for an aerospace equipment manufacturer. It is located in the USA.

The company's formal product development process for the front-end consists of three steps and one review stage (or screen). The company uses a common methodology for both commercial and defense interests. Additionally, technology development is closely intertwined with the company's front-end development process. The following diagram is illustrative of the company's process and will be followed by a discussion of its elements.

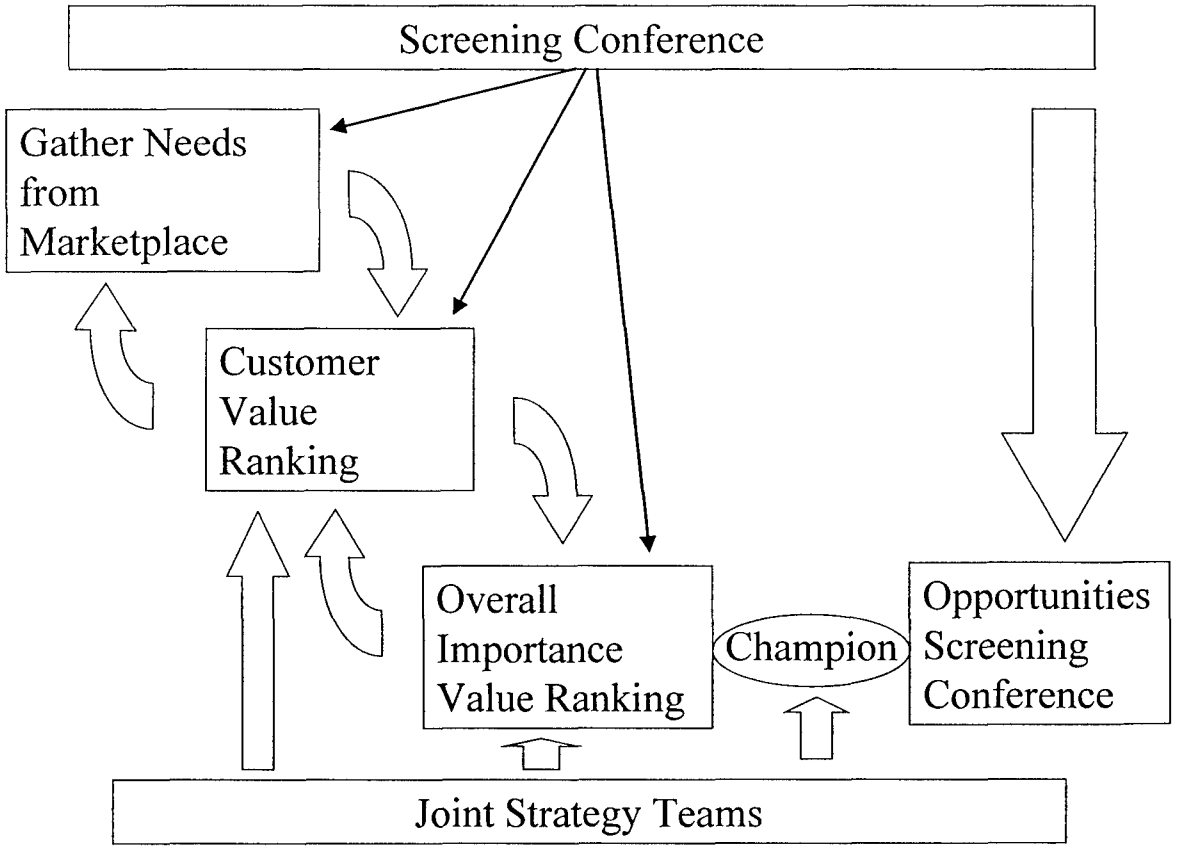


Figure 34. Company F's Front-end Process

As a brief overview of the entire product development process, there are several activities that take place. Prior to their first gate in their business development process, is a 'Create Business' pre-process. It consists of three steps plus one screen. First, the company starts with needs (gathered from the marketing department) and feedback from current company products, and then the company seeks to develop opportunities derived from those sources. Next, the company will sort and prioritize the opportunities, then align potential products and customer needs, and finally develop the business plans. Upon approval of a business plan, the formal product development process begins and the company will acquire the required business processes, develop the recommended solutions, and finally deliver the finished product to the customer.

Returning to the first step in product development for a more detailed discussion, the first step is to determine the needs that exist in the marketplace and the defense sector. Marketing personnel are constantly gathering new ideas. Those personnel gather ideas for the defense sector by using concept papers and attending wargaming exercises to find out what the military believes is necessary. Additional sources for the defense sector include information from demonstrations; experiments; the service laboratories; Battlelabs, etc. Other sources can be top-down directed as well as originate from employees of the company.

Marketing takes the information from all of these sources and thoroughly analyzes them to get as far upstream (or ahead in the product development) in the process as possible. Marketing integrates customer requirements/needs across mission areas for their defense customers and also across different markets for their commercial customers. They use multi-disciplinary IPT's as part of their core processes. A separate IPT is responsible for each 'mission area' and/or market. In the case of technology development, for example, one IPT will identify, prioritize, and fund needed technologies.

The process for technology development uses 3 sets of inputs. 1. Existing company programs, 2. Advanced programs & concepts, 3. Pure applied technology research programs. These constitute the source of most of the technology development efforts.

For a new product opportunity to exist, the IPT evaluates the following factors: the Customer Requirement, if funding (by the customer) is available, the current amount of political support (for military programs), and if the required technology is available. These criteria drive the answer of the

metric, 'Potential to go', for developing a technology or concept. It is a qualitative measure used to gauge the relative merit of a given project. There are also several enablers to 'Potential to go'. These enablers are technology demonstrations and studies, R&D, test programs, Advanced Technology Demonstrators (ATDs) and Advanced Concept Technology Demonstrations (ACTDs).

The second step is to quantify the 'performance' of the concept against the 'pure' needs of the customer. They do this by using the QFD process to map the identified needs to potential solutions / requirements. The solutions that come out of the QFD process are then ranked according to a tool, called a 'Customer Value Ranking Tool' that tries to quantify the 'utility' or 'worth' of a solution to their customer. They believe that this step brings them to at least the 80% solution. Each concept is ranked separately to prevent bias, and the corporate bottom line, company values, and potential to win are NOT considered at this point.

The overall prioritization scheme for judging the various concepts is based on the following criteria. The criteria seem to be equally weighted. The first criteria is the Customer Priority (in the case of the military, customer priority is based on three things: a) funding stability, b) program stability (program requirements and objects remaining stable, key personnel stability during the military front-end development, etc.), and c) the importance (financially) to the company.) The second criteria is the Merits of Business Case (i.e. profit element, NPV, etc.). The third criteria is Value (to shareholder, general public / stockmarket). The fourth criterion is the match with Company Values. The last criterion is a Potential to Win evaluation. The Delphi Process was used to determine the weights of the criteria used (looking at trends across successful programs/solutions as well as inputs from the senior, more experienced employees).

Time plays a factor in these projects as well. The company will also use the information communicated by the five criteria above to sort concepts along three different time horizons. It is important to understand the importance of the 5 pieces of data relative to the different time horizons. They use three time horizons: Near = 0 - 3 years; Mid = 3 to 10 years; and Far = 10+ years. Anything beyond 15 years is considered too far out to anticipate and plan for. Therefore, in the case of a new idea for a military concept, the idea is most likely to be allocated to and sorted among either the Mid- or Far- time horizons. This gives the company time to further develop and refine the concept for the

company's marketing people to use in lobbying the military departments about the company's capabilities.

For instance, the company uses a notional heuristic for judging when to have a military system concept developed. An example case for military system will assume that from the beginning of idea formation, it takes about 3 years for the political sponsorship to get to the needed point for the military to initiate its Planning Process. The process then takes another 2 years for the Planning process to verify that enough risk reduction has taken place to reach acceptable levels for the military to begin the concept's development (i.e. writing a Mission Need Statement). From this point, another 5 years can be expected until the necessary funds are in place to begin full-blown development work (approval and validation of the initial ORD).

Oftentimes, as a customer develops the requirement for a product, the Concept of Operations is the weakest part of the customer's requirements document. Most customers do not know exactly how they will use a new product. Therefore, the company has set up a special group to develop operational concepts further. This is done just to understand the requirements better (and marketing can use it to influence the customer's understanding of the use of the product). For instance, when the Air Force does an Analysis of Alternatives (AoA), the company will usually run a 'shadow' AoA study (using the company's organic capability).

During the third step, the solutions are again sent through the QFD process, but this time the solutions are scored against 'Company values' and a 'Potential to Win' criteria. These are the remaining items from the five criteria that had not yet been considered during the QFD process. Different and separate teams (from the Developing IPTs) are organized along mission areas and/or markets to specifically do the second round of QFD scoring. They do not take a position of advocacy on any concept. These teams are called 'Joint Strategy Teams'. They meet as required and also at least once a quarter.

This step of the process is where the sorting and prioritization takes place. However, it is still too difficult to build a list of prioritized concepts ranked from top to bottom. Potential solutions tied to customer requirements are broken into two 'tiers', Tier 1 and Tier 2, along the near, mid-, and far time horizons. Tier 1 includes those concepts that the company believes are most likely to succeed. Tier 2

are those that are less likely to succeed. At this point, the business case for the concept is built, usually only for those concepts listed in Tier 1.

Once the scoring is complete, the company usually assigns someone from the Joint Strategy Team to be the 'Champion' of a concept. The champion is someone that understands the concept and is its advocate, helps with the concept prioritization and defends the concept or technology during management reviews.

When a concept's business case and its requirements are presented to the screening function (called an 'Opportunities Screening Conference'), the concept champion is allowed to present 3 or 4 PowerPoint-type slides. One slide is about the 'Employment process' or how the concept will be used, and the other slide is about the 'Product/System Overview'. The last one or two slides are about the 'Importance to the Customer' or the team's interpretation of how important the proposed new product is to the customer and the likelihood of the customer to acquire it.

The 'Screening Conference' occurs regularly to finalize corporate strategy and approve business cases. They usually meet quarterly and also get monthly reports on project status. (The Opportunities Screening Conference is a subset of the Screening Conference specifically called to evaluate business cases.) The conference decides the actual strategy (officially) just once a year (as their budgeting process is done yearly.) The conference looks at all of the solutions from a business unit perspective. They have no advocacy and are independent. The members of this conference are the different functional directors (company Vice Presidents for those functions) and the conference is chaired by the company's overall Vice President. Each concept Champion presents information to the Conference regarding the work that has been done to date on a given concept or presents the finalized business case. Advocating a particular concept can be a long process for Champions as some of these concepts are in the Far Time Horizon.

Once approved by the Screening Conference, the concepts are identified as 'New Opportunity Creations'. In practical terms, these things don't yet exist in the DoD's Future Years Defense Plan (2 to 7 years away) or in commercial company's strategic plan. The marketing teams take over after the Conference has approved a concept's business case. They take the concept/product to the customer and try and sell it. (Here is also where the relationships between the Air Force's Technical Planning

Integrated Product Teams (TPIPTs) and other military organizations (like Battlelabs) and the company's technical support become more like Marketing activities. In practical terms, this activity is most closely related to the military's planning functions that determine potential concepts for capability deficiencies or identified needs.) Depending upon the customer's interest and upon receiving any knowledge of a customer budgeting money to purchase such an item determines any further movement of the approved concept and project into the regular phase gate product development process this company uses.

Overall, the process is done at the beginning of the company's fiscal year and takes anywhere from 3 to 6 months to complete (depending upon the complexity of the concepts being debated). In 1988, approximately 140 new concepts began the process and only about 75 completed it. Some of the concepts were combined with other similar ones and others simply weren't able to finish. Additionally, no information gathered during this process is 'thrown away'. All of the information is stored and maintained in a computerized database to avoid potential rework, even for those concepts that didn't complete the process. The potential remains that a concept could be used in the future. All of the company's IPTs and Marketing personnel as well as members of the conference have access to this database. It is not available to everyone in the company.

Organizational Issues

The organization is matrix-based. Teams are formed across mission areas and also markets and draw their members from functional organizations. These teams mature ideas from 'conception' through the development of the business plan.

They use an Excel database to track technology development. They use a much larger database (with a centrally assigned number that has the capability to 'screen' for duplicate efforts across the other business units, etc.) to store and track their ideas and concept development process for the front-end.

Business Issues

They have an annual budget process that defines their resource allocation process. The process itself only takes about two months to really get through. This process occurs just prior to the beginning of the company's next fiscal year. Ideally, this occurs immediately after the completion of the front-end process. The Resource Allocation Process is being updated to reflect a more integrated approach to

new product development. They are still working on a more thorough integration of strategic planning, product prioritization, etc., portions of resource allocation.

Besides dealing with technology development specifically tied to current projects, about 20%-25% of the company's Internal R and D (IRAD) budget goes to applied technology research activities. The IRAD however, is very oriented towards the Contracted R and D (CRAD), which is focused on potential products. The current mix is about 70%/30%. The topics for study on the military side fall directly out of the Science & Technology (S&T) roadmaps. 80% of their IRAD is tied to an S&T product or service. (Hence their IRAD funding is also directly tied to the size of the S&T budget - which has been steadily decreasing over the past few years).

For example, on the military side, they map their IRAD projects directly against the Air Force's Air Combat Command's (ACC) top S&T deficiencies (as found in the ACC Mission Area Plan). They are also actively engaged with the Air Force Acquisition Community and Planning processes through the TPIPT process.

Additionally, the company believes in pursuing certain technology developments even though they may not yet be tied to a specific product or technology. A portion of the company's annual IRAD budget (approximately 5 - 10%) is allocated to technology efforts that support growth technologies the company feels will be important in the far-term. This portion of the budget is prioritized and allocated through a technology prioritization process (separate from the business development process described in this case study) administered within the technical community in the company. These are generally not yet associated with acknowledged products or concepts and are usually high-risk from a technological development standpoint. It is acknowledged up front that not all of these will succeed, but the overall effort will produce the seed corn for future systems in the 15-plus year time frame.

Summary

Company F has a robust front-end process. Many aspects of the process mirror those advocated by the framework. It is clearly tied to their strategic focus and also their primary customers, although the method of gathering needs is different between military customers and others, as one might presuppose.

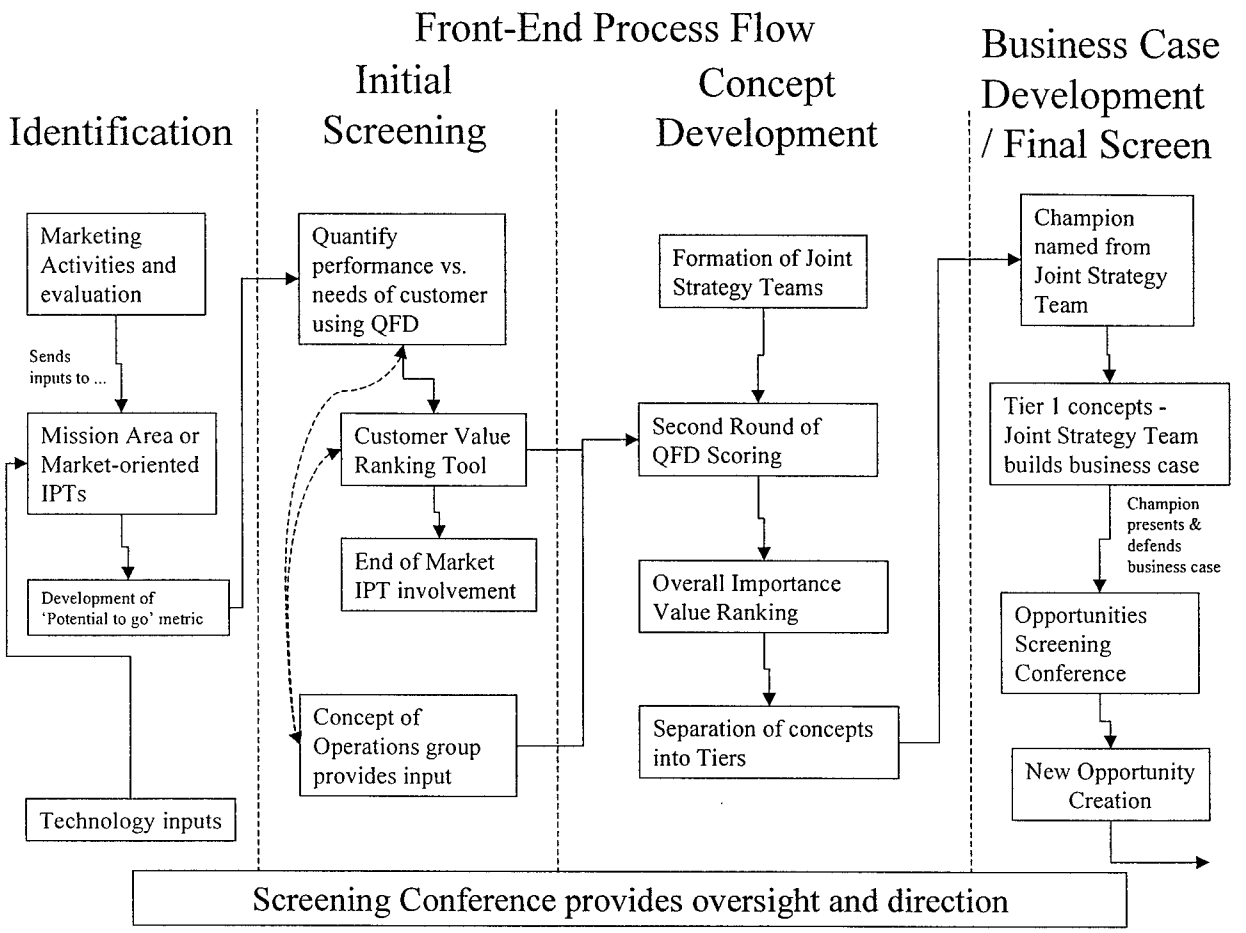


Figure 35. Company F's Front-end in Terms of the Framework

The process uses a quantitative tool (QFD) to bring rigor to the process and uses clear criteria that must be met in order to proceed to the next development step or phase in their process. One advantage of this process is that it acknowledges some concepts that are of value to a customer may not be the best 'value' to the company. Therefore, a mechanism is in place to evaluate and make tradeoffs in this area.

One organization is responsible for the development of new concepts. Additionally, one team is responsible for the development of a specific concept or concepts. Furthermore, a 'champion' is dedicated to making sure the screening committee reviews the concept in the best 'light' possible.

This company takes a different approach between the commercial and defense sectors. The sectors differ due to the 'freshness' of the concepts that actually move into their formal product development process. This means that a 'defense oriented product' will likely be pursued up to seven years prior to actually beginning development work on a project. The commercial sector has a shorter delay time as their processes move faster than the defense procurement process. Therefore, a defense-oriented concept can be much more radical in what it promises to deliver (in the hope that technology developments will enable the feasibility of the concept by the time such money becomes available) than a commercial concept will be. Interested commercial parties could easily seek such a concept soon after the commencement of the company's marketing activities.

Company G

Company G is an end user in the airline industry. The company is headquartered in the USA and operates throughout the world.

The company uses a process to determine fleet development strategy. The company's front-end is typically in the domain of the marketing department. However, the company's process has many interesting traits and will be discussed below. The following diagram shows the process.

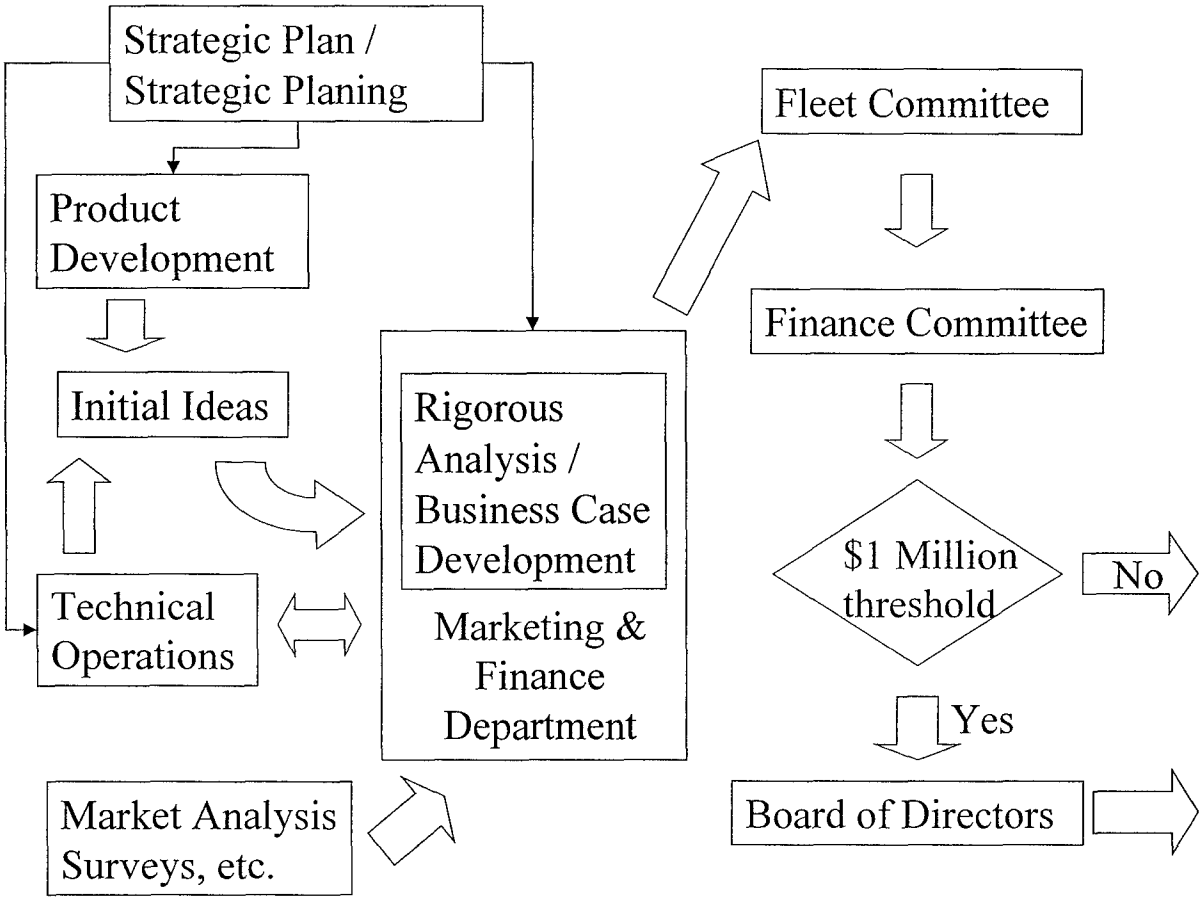


Figure 36. Company G's Front-end Process

The Initiative for a new product almost always comes from within the Marketing department. However, new initiatives might come from operations, or even finance depending upon the conditions of the market, or the conditions of the fleet. For example, marketing will try to identify opportunities on how to transport more or make the decision to retire a piece of equipment.

There is one formal step and three screening committees. During the first step, the marketing department creates a proposal. It is then reviewed by the financial and operations departments. According to the company, the finance department is usually the most skeptical and operations is likely to be the most receptive to any new initiative. Each department has a specified time period to review each proposal. The length of the review period is case specific - but it is about a month on average.

The effort of building the proposal begins by framing a 'problem statement'. Once this problem statement is determined, a market survey is conducted concerning the issue. The target of the survey is conditional. For a product most likely to affect crewmembers, the other airline companies are researched to determine their position. For a product that will directly impact its customers/passengers, market surveys using statistical sampling methods will be used, often across the different customer segments (business vs. pleasure travelers). Oftentimes, the marketing department doesn't rely on market research. The department will use their in-house experts instead.

There are two primary categories of product development decisions at Company G. First, there is the buying and/or disposing of large capital equipment. Second, there are modifications to the capital equipment. (There is also a third category - other aircraft decisions - these go through a much shorter process.)

With the 1st category, the company has a 5 and 10 year plan for their domestic market. It is a very sophisticated exercise where many factors are accounted for, including anticipated demand in a market (plus the fare environment/traffic - impacts on revenue), the costs (fixed, variable, costs of ownership, etc.), the equipment types the company has, and etc. From this the company will come up with a general plan like the type of equipment with a specific amount of capacity that is needed for a particular market. These plans are working documents. One is called the "Fleet Outlook Plan". Every two years, the plans are redone primarily because the plans are hard to do, and enough changes have usually taken place within the past two years to warrant a revisit.

The 2nd category is that of modifications to the capital equipment. First, the company evaluates the number of units involved and figures out what is required to do the modification. The result is a plan on how it will fit into the normal checks, maintenance, and schedules of the equipment in use.

Generally these kinds of modifications fall into two categories: mandatory and non-mandatory changes. Mandatory changes are usually those where the customer doesn't know to care about them. These are usually changes that affect none of the customer's senses during the trip. They are largely 99% technical as well (i.e. government regulations & safety issues). These are done as cost effectively as possible.

Non-mandatory changes require rigorous analysis. Two different departments usually do these types of modifications: Technical Operations & Product Development. Both of these departments are customer-focused. Maintenance needs are usually done by Tech Ops. Customer needs are done by Product development. The focus of the Product Development department is on customer perception issues. This usually boils down to two types of issues: Competitive (e.g. the company's competition is doing it, service, sensory experiences of their customers, and simply keeping up with the Jones'.) and non-competitive ones.

A third category consists of anything else that doesn't fit into the above two categories. These consist of usually small decisions less than $1 Million or tactical decisions like timing decisions or pricing decisions or price matching. These are fluid and could not be done through a long process.

The previous two categories of modifications to capital equipment (mandatory and non-mandatory changes) take approximately 2 months to get ready for approval. The time required to get something ready for approval is due to the analysis process.

Analysis is done using the following: surveys, market share reports; and using information gathered to show cause and effect relationships. The last step is the most sophisticated. The company evaluates the proposals with the market and the other mentioned factors by using models and simulation. One example of this is the company's Fleet Model. It addresses all aspects of the company's 'Fleet Outlook Plan'. It is a Mathematical Integer Program. The plan takes two points in time, 5 & 10 years, as a starting point. The mathematical program will concentrate on 3 things given the assumptions and constraints they have. The company assumes a given schedule and tries to optimize the equipment on a schedule that will make the most money and also take into account regular maintenance and special maintenance requirements. The constraints are things like maintenance and performance targets. The first item is "Spilled Revenue." It is a function of available space - demand vs. capacity (this drives solution of the program to meet demand 100 % of time, but this is not optimal.). The second is Operational Costs. This drives the solution toward smaller equipment (smaller the equipment, the lower the costs). The third item is 'Ownership'. This includes the cost of purchase, operations, maintenance, etc. The objective function of the model is to minimize costs.

After these models are used, the marketing department will prepare the proposal. The proposal is basically the business case. The marketing department constructs it almost entirely themselves. In incremental decisions, it is pretty much a straightforward marketing department decision. For a replacement decision on a fleet-wide basis, the marketing department still takes the lead (usually), but there are 2 or 3 additional key factors in the decision. The models are used to help answer the questions.

1. Can the company make more money with the new equipment?

The marketing department looks at the revenue production ability of the new equipment. These are things like range, capacity, fuel efficiency, etc.). Will there be increment revenue that will offset the costs?

2. How much is it worth to the company - what is the effect of the public (potential customer) perception of these products?

Any proposal can bring about many changes, some of them unanticipated. In essence, a ripple effect can be created with new equipment acquisition that extends across the entire fleet. If new equipment can be placed on routes that are 'payload constrained' such that the new acquisition relieves or reduces that strain on those particular routes, other equipment can be moved to other routes to decrease the constraints that exist on those routes. Hence the 'ripple' effect. This can be very beneficial, especially on those routes that are no longer payload restricted because of the new product.

The criteria used to evaluate all new product proposals include 'Internal ROI' and 'NPV'. NPV justifications are really the bottom line vs. qualitative reasoning concerning any modification. The company does not track rejected proposals. The marketing department won't allow a proposal to leave their department that could be killed, so the company has a 0% rejection rate at the concept screen. All proposals must go through the marketing department, even those that do not originate in marketing.

From this point, proposals enter the formal review and approval process. Each committee has the power and ability to 'turn back' a proposal or even kill it. However, this almost never happens.

The first review committee is the Fleet Committee. Its members consist of directors and officers of the company. It meets approximately once a month. The second review is a Finance Committee. Membership is similar to the Fleet Committee. It also meets approximately once a month. The last review is by the Board of Directors. Projects worth more than $1 Million go to the Board for approval. The Board membership consists of the board of directors of the company. The Board meets at least once a quarter.

Organizational Issues

This company has two types of customers that drive very different behaviors. The first type of customer is the employee within the company that operates or maintains the equipment used by the company. There are issues with new equipment, features, and retirement of existing equipment that have to be dealt with such as training for familiarity and correct operation. The second type of customer is one who pays the company for the service of point to point transportation. Here the market is based upon the senses of the customer or the experience of the customer while receiving the service.

For this reason, the company has two distinct planning departments (fleet & market) whose needs have to be reconciled. Oddly enough, there are two other departments (marketing & a 'negotiation' department (between marketing & finance)) that tend to act as a 'forcing' function for this reconciliation to occur.

Business Issues

The Board of Directors mandates the goals and objectives of the company. The company uses a lot of MBO (Management by Objectives) Planning. It provides an overall framework for the coming year. However, that list is flexible – anyone wanting to change the list just has to justify the changes. These corporation objectives translate into the actions the company will take in the current year. But at the end of the year, the company has to reconcile the two (actions taken vs. what the framework contained) - Bonuses are based upon this reconciliation.

Priorities are also based on the MBOs. But these change. It is therefore important to have contact with the senior management. Anyone pursuing a new product has to have senior management's buy-in.

All plans they have are taken care of and updated. It is usually top-down directed.

They plan a budget. But they do not execute the budget...it is a plan only. It serves as a benchmark. If an NPV analysis comes up with a positive result for a new concept, developers execute it immediately and don't worry about it after that. The finance or accounting departments end up sorting things out. Nevertheless, some departments are budget focused and others are not. To understand what focus a department has, ask the question, "What is the mission? What value do they add to the company?" For example, an existing airport gate is value focused. They need to turn the equipment around quickly and get it back out on time.

Fleet and/or Market Planning is not as focused on the budget. (They use the budget mostly for employee headcount allocations). But because these departments spend money to create value, they still have to be aware of the resources that are available.

Summary

All of the screens seem to be in place in order to build consensus or organizational inertia. This judgement stems from the observation that the marketing department won't let anything forward that could be killed. The marketing department is THE filter for the front-end new product development process.

New ideas come from many areas and are initially developed by multiple organizations. The marketing department takes all of these ideas and removes any overlapping ideas. The company makes no mention of cross-functional idea development.

The following diagram depicts the company's process in terms of the idealized framework.

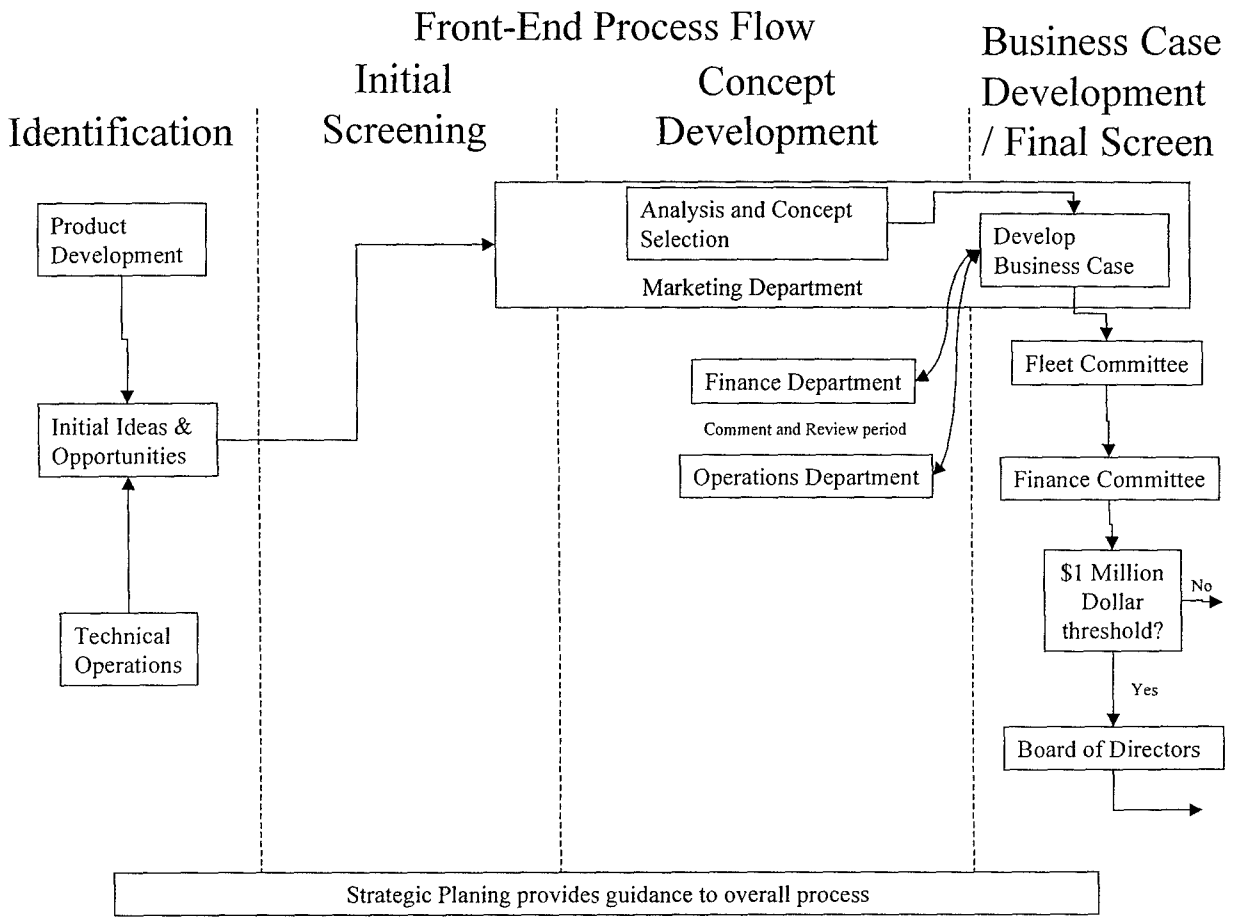


Figure 37. Company G's Front-end in Terms of the Framework

The company shares some traits with the proposed framework, such as conducting rigorous analysis on new product decisions; establishing Criteria for the product requirements; and tying new products to the strategic plan of the company.

Company H

Company H is an end user in the airline industry. It is headquartered in the USA. The company's product development process is well defined. It is also distributed. Items relating to the operation of the equipment will come from the different functional areas of the company. The following diagram outlines this process and a discussion will follow.

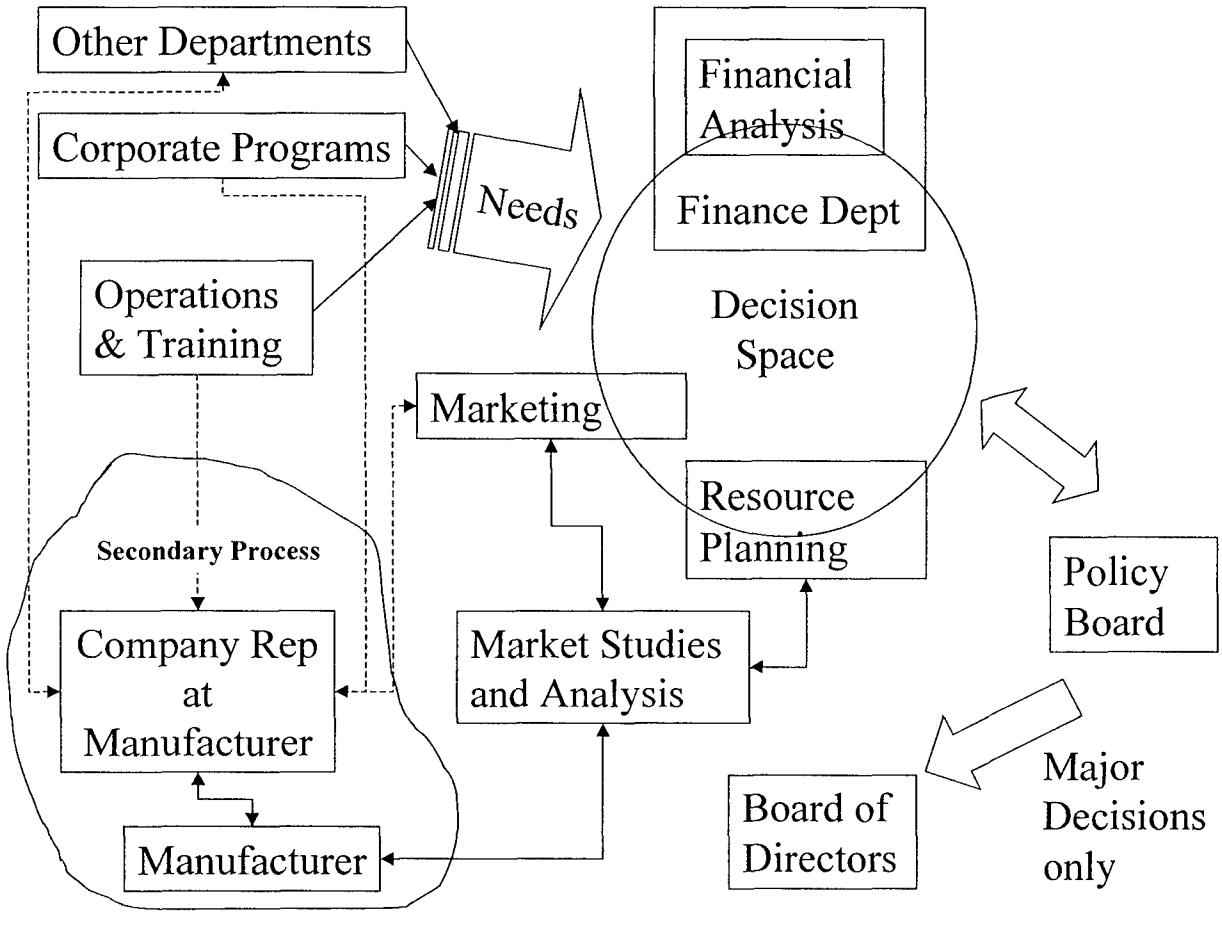


Figure 38. Company H's Front-end Process

Identification of needs and suggestions for new solutions can come from anywhere. Operations (& training) is a huge source of operator needs (and usually a solution as well). As Operations & Training or another department tries to get a need filled, that department also might use a few numbers in terms of cost with the department's request, but these numbers are really 'soft'. The company usually passes any ideas on to whichever department deals with that type of specialized equipment (for a first look). The only time things wouldn't come from Operations revolves around reliability issues. Also, Corporate Programs translate the wishes of the CEO (top-down directed – "I want to exceed our competition's ability on the X to Y route") into requirements for new equipment, if necessary.

The next step in the process is with the financial department. The department does an estimate on the Total Ownership Costs (TOC) and the revenue potential of the equipment. The estimate includes

things like the lowest cost per mile. Developing these models is the hardest part of the analysis. The financial department has its own studies group where ideas and solutions are bounced off of the models.

When comparing technical requirements vs. finances, the financial department analysts usually rule the day. It usually boils down to the financing capabilities of the different companies selling equipment. That feature has the most impact on the process.

Resource planning personnel make the decisions. This department works closely with the Financial Analysis group. The priorities for new products are set in a forum between the two departments. Marketing personnel have a strong influence here too. As technical requirements are analyzed, the company uses 11 categories to prioritize and rank. Mission capability is the most important. The other factors are things like interior, maintenance, technology state, and infrastructure capability. The ranking is usually done using a 1 to 5 scale. Subsystems are evaluated more thoroughly. The lowest criteria on the list were features for the equipment operators. Big changes, especially marketing changes, go all the way to the board. Usually it is a token decision. The decision cycle for these kinds of proposals is only 2 or 3 weeks.

The forum members use 'Consumer Reports' type of charts for their senior management to compare competing designs. The contracts group in Finance put together 'term sheets' – which are done on a contract level and contain ratings/rankings of different manufacturers and their offerings against a common baseline. Sometimes there are up to 50 items on the sheet and are very specific (e.g. size of the training documentation).

Before any item reaches the board of directors, a policy board may go through 2 or 3 meetings (1 per week) to iterate the mix of requirements and solutions. Finances really drive the requirements of a proposal. Without numbers supporting the requirements, the company just can't justify the expenditure and the proposal is killed.

Documents (for requirements) consist of letters to the manufacturers (this is outside of contractual documents). They are logged-in and tracked by the manufacturer. The company has one person dedicated to transferring the company's desires to the manufacturer. Sometimes, this person is co-located at the manufacturer's facility.

Coincidental with having a company representative with the equipment manufacturer is another part of the product development process. It is secondary to the main process and can also occur informally before a contract is negotiated or signed with the manufacturer. In the context of the secondary process, this employee supports the main new product development process by ascertaining the capabilities and potential costs of a project through consultation with the equipment manufacturer. The employee then feeds this information back into the initial front-end development work. The process operates in the following fashion. The company representative waits for letters or requests for information to come in from a 'company focal point'. These 'focal point' people number about 15 or 20 and are known as official 'requestors' within each of the company's departments. If things come directly to the company representative from the 'field' and not from a focal point, the request is redirected back to the appropriate focal point within the company. Requirements in this case are mostly 'bottoms-up'. Often, the equipment manufacturer's marketing department has already considered the needs of its customers and the requested information has already been gathered. Usually a response can be sent back to the originator within 24 hours. Usually the information is used by the requesting department to further pursue its product ideas. This will be fed into the main front-end process from the originating department. The information received from the manufacturer is usually the source of the 'soft' numbers that are passed up with the proposal.

The company also has a New Technology Engineering Group. This group acts as the gatekeepers for technology insertion. Technology insertion is handled two ways. One is outside 'rule-making'. These are decisions forced upon them by governments, etc., for safety or other regulatory changes, etc. The company may lobby hard against some of these changes, but once the decision is made, the company won't fight the decision. However, the choice of the supplier is not dictated so this choice is usually based on the after-sale support, as well as being able to meet the requirement. The second method of technology insertion is done on a 'voluntary basis'. Voluntary technology insertion is much more difficult to accomplish or even to succeed in getting a project of this kind approved, as it must be justified to the financial department.

The company does some limited R&D on things like paint and some highly specialized equipment. The company used to have R&D in everything and at one time even had a 'clean room' just for the specialized equipment. This is no longer the case as it is now all farmed out. A component shop is

still around for some organic maintenance and repair, but now most repair work is sent directly back to the manufacturer.

Organizational Issues

The overall makeup of the front-end is dispersed. Every department may participate in the front-end if it chooses to do so. However, the number of people that are known to really identify needs and requirements is a small number of people. The people in these positions have been there for a long time. The person who is the contact with the major equipment manufacturers knows all of these individuals and understands the process.

The development of the company's strategic plan is often personality driven. The process is not usually repeatable. It carries a lot of biases (personal vision that seems to change from year to year) from the person that was tasked to write the report. However, the process seems to be repeatable when fleet replacement/new purchase decisions come up. Part of this comes from the rigor associated with new acquisitions.

The company is organized into fleets that correspond to the different types of equipment the company operates. Each fleet has a Fleet Captain, a standards person, and training personnel. These people are often the source of many ideas and are responsible for different things for each fleet. The company has learned that with huge fleet sizes of 50 or more of the same model, whole support packages of things like training, maintenance, etc., can be developed cost effectively.

Business Issues

The company uses one common heuristic they have learned over the years: 'don't go with the lowest bidder', especially with developmental systems.

The entire front-end process is usually non-stop and lasts about 6 months until the company actually decides to sit down with the manufacturer and start contract negotiations. At this time, most of the specific technical requirements are already known and not a point of discussion.

The Strategic Plan is written/updated every year. It looks out 5 years. Every 5 years the company writes a Rolling Fleet Plan. It revolves around a market forecast and population shifts. It addresses fleet mix and capabilities, including slot restrictions. It is very high level and simplistic. For example,

1999 there may be a goal for so much used capacity per trip to Hong Kong in aggregate numbers (hundreds of tons). The fleet plan is shared with the manufacturers. The manufacturer usually already knows in advance what each company in this industry needs. The manufacturer usually comes to the company with their ideas in similar areas. So, the overall effort for product development seems to dovetail with the manufacturers' marketing efforts. However, there are other manufacturers in this industry that usually aren't so proactive.

Summary

This company has a formal front-end process. It shares many of the same characteristics of the framework. The following diagram captures this company's process according to the structure of the idealized framework.

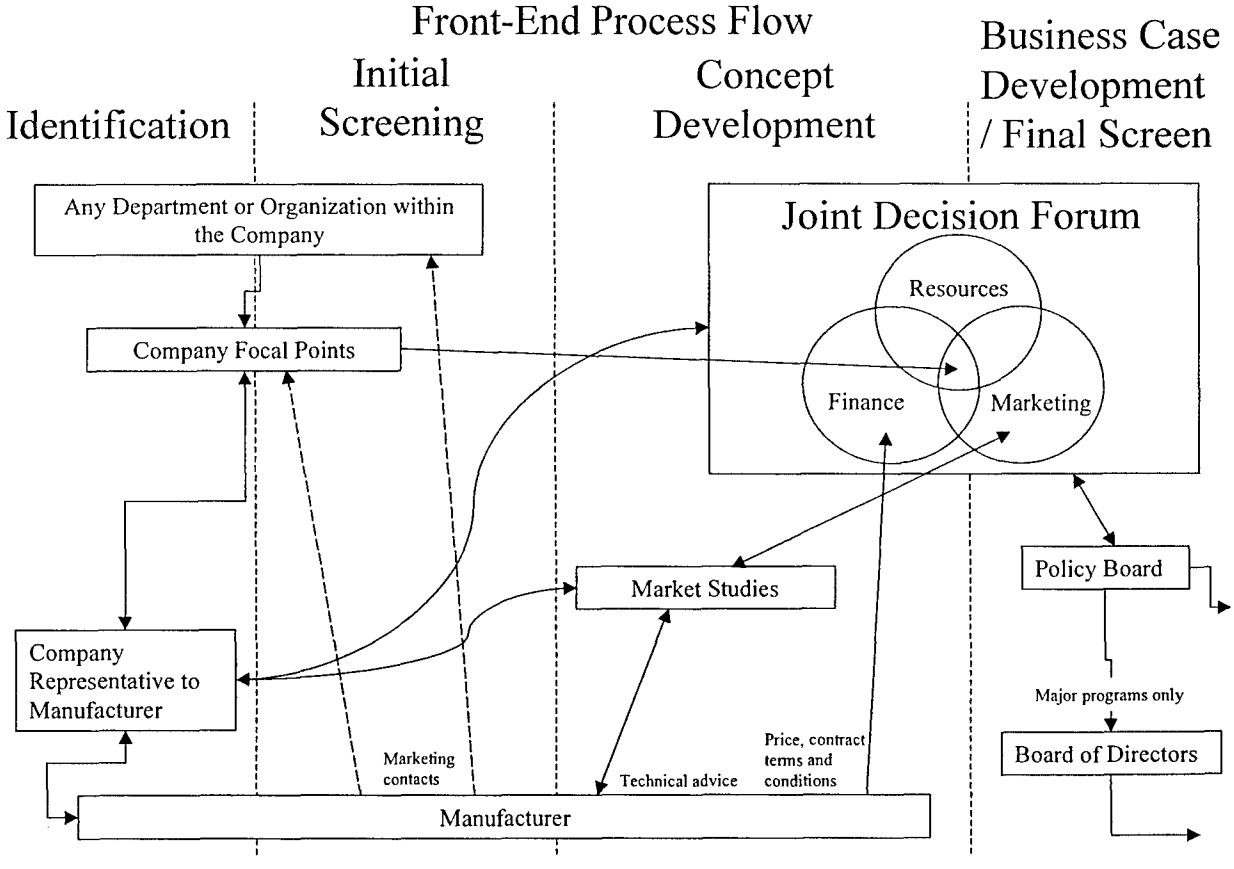


Figure 39. Company H's Front-end Process in Terms of the Framework

One of the distinguishing characteristics of their process is the unique and close relationship the company has with one of its primary manufacturers.

Another feature of note is that 'Resource Planners' take the lead in determining priorities for the company. This is done in an integrative atmosphere with participation of many departments, Finance and Marketing especially.

Military Organizations

There are three kinds of military organizations that are described in the following case studies. The first case study represents another nation's attempt at dealing with the complexities and issues in the front-end of product development. The second represents the remaining three military departments of the United States. The last type of military organization described is that of the Unified Commands, which are made up of end users.

French Procurement Agency

The French Military's way of conducting product development is very similar to that of the United States. However, the main differences between the US model and the French way of doing product development are found organizationally. Their Acquisition authority, called the Procurement Agency, is on the same level as their Joint Chiefs of the different services, Support Functions, etc. Each of these entities reports directly to the Ministry of Defense. The Procurement Agency was created in 1961 and is the source for weapon system development for the French military in peacetime. During wartime, product development is shifted under the direction of the Joint Chiefs. To date, this has not happened.

The overview of their process is presented below. Detailed explanations of the different steps of the process are included in the discussion.

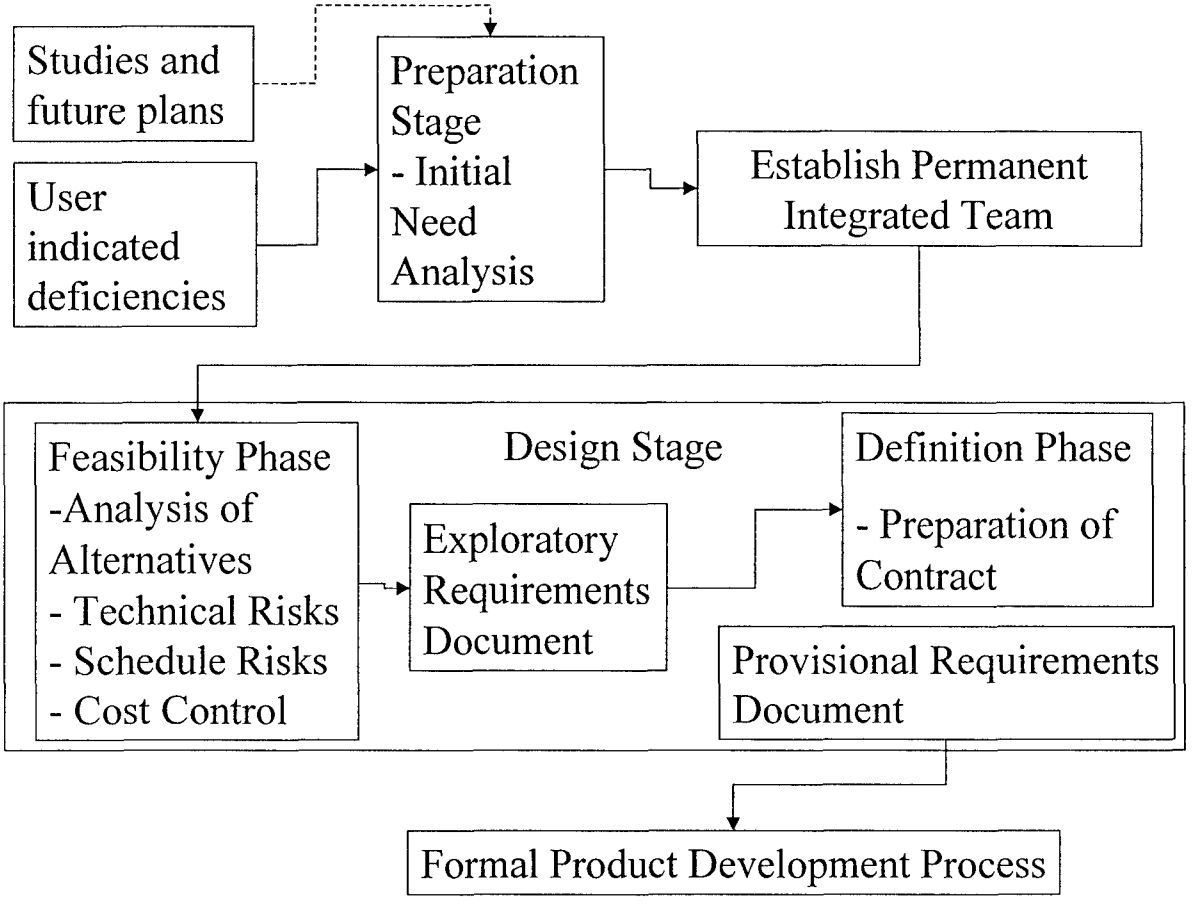


Figure 40. French Military Acquisition System Front-end Process

The entire front-end of the French Military Product Development Process is run and managed by one organization, the Force Systems and Futurology Directorate of the Procurement Agency. The Procurement Agency has direct control of nearly 80% of the Defense Departments budget, with the other 20% used for operations in the services. Additionally, the procurement agency is responsible for the entire product development process for the French military, including the timing of system retirement decisions.

The process begins with the strategic planning conducted by the directorate. The authors of these strategic plans are 8 Force Architects and a similar number of Operational Concept Officers. (In this discussion, the terms Architects and Directors coincide with Procurement Agency personnel and 'officers' coincide with French Military personnel.)

These plans postulate the next 30 years of threats and weapon system development. The plans form the framework of understanding for the development of new weapon systems and are the measure by which new product development opportunities are measured.

The Stage of Preparation is the first stage of the process after identification of deficiencies and needs. This stage contains a very important screen. Here, all user needs are collected and screened at this stage by the Force Architects, and the Officer in Charge of Weapon System Coherence. This committee, in close collaboration with the different military force staffs, will determine possible solutions, clarify the military need based on studies, determine the functions of the new system, and establish basic cost estimates of the system. (This is analogous to a combined Mission Area Analysis and Mission Solution Analysis done within the US military.) Should these all align with the vision outlined in the 30 year plan, and there is money available in the budget, given the current existing constraints, the requirement moves into the Design Phase. The normal duration of the preparation phase is approximately 2 years.

The onset of the design phase occurs upon the establishment of the Permanent Integrated Product Team, lead by a Program Director and also a Program Officer. The Program Director and Program Officer are the equivalent of a US Military 1-star officer. The team consists of three types of people. The first group of people belongs to the Acquisition Corps and come from various functional backgrounds. The second group is drawn from the different military services, as required. The last group comes from industry (There are many government owned, subsidized companies in the defense sector and there are few barriers between the Ministry of Defense and commercial companies). The team's primary objective is to obtain the best relationship between cost and performance.

The Design Stage has two major phases. The first is the feasibility stage. During this stage, the requirements are analyzed extensively. (This is analogous to the US Military's Analysis of Alternatives (AoA).) Risk reduction methods are required and cost is actively traded among the system requirements. The output of this stage is an 'Exploratory Requirements Document'. (This is not analogous to a MNS or an ORD in the US Military – it is closer to a draft Request for Proposal).

The Definition Phase is where detailed analysis of the requirements takes place. The loosely defined requirements from the first stage of this process are defined with much greater rigor. The output of

this stage is the Provisional Requirements Document. This will form the core document around which a contract will be constructed. (It is very analogous to a Systems Requirement Document in a US Military setting.) Additionally, the team provides a set of criteria and measures by which the remaining product development will be measured. These mostly consist of milestones, cost, schedule and performance data. The incentives for project and organizational success are defined by these measures. This process normally takes between 2 to 4 years.

At this point, the program is assigned to a new directorate within the Procurement Agency. This is the Weapons Systems Directorate. The 'Programs, Procurement Methods, and Quality Directorate' assists them. Together these two teams bring the proposed system into development and later into operation. As soon as the system has transitioned to the new directorates, a contract is awarded to a contractor for the remainder of the program development.

Organizational Issues

The process uses one organization and one team to steer the initial development of the system. The team consists of permanent members who are authorized to act in behalf of their respective organizations.

Additionally, the board of architects and senior officers constitute the screening committee at the earliest stages of the process. The architects maintain their connections to the ongoing process due to their strategic and oversight function within the procurement agency.

Architects and the Permanent Integrated Product Teams as well as the introduction of the Preparation Stage are the result of a 1997 Procurement Agency restructuring. The restructuring occurred to comply with a French Law requiring it to do so. The Preparation Stage was added to put more discipline into their product development process.

Business Issues

The Restructuring of the Procurement Agency was done primarily for financial reasons. The restructuring was done to reduce by 30% the cost of weapon system development programs during the period of 1997-2002. It also was mandated to reduce the cost of government subsidies to the defense industry by 30% during the same period. Finally, the law required that the market share of foreign defense sales increase to approximately 15% of the world market.

Finances for the defense department are funded over a five-year period by the French government. It is the responsibility of the Ministry of Defense to ensure that the various departments within the ministry, including the Procurement Agency, manage those resources wisely.

Summary

Overall, the process contains many elements of the idealized framework. The procurement agency can be compared to a large company that begins its process by listening to the user. One of the overall differences in this process is that the user has representation on all of the product development teams as well as the initial screening committee.

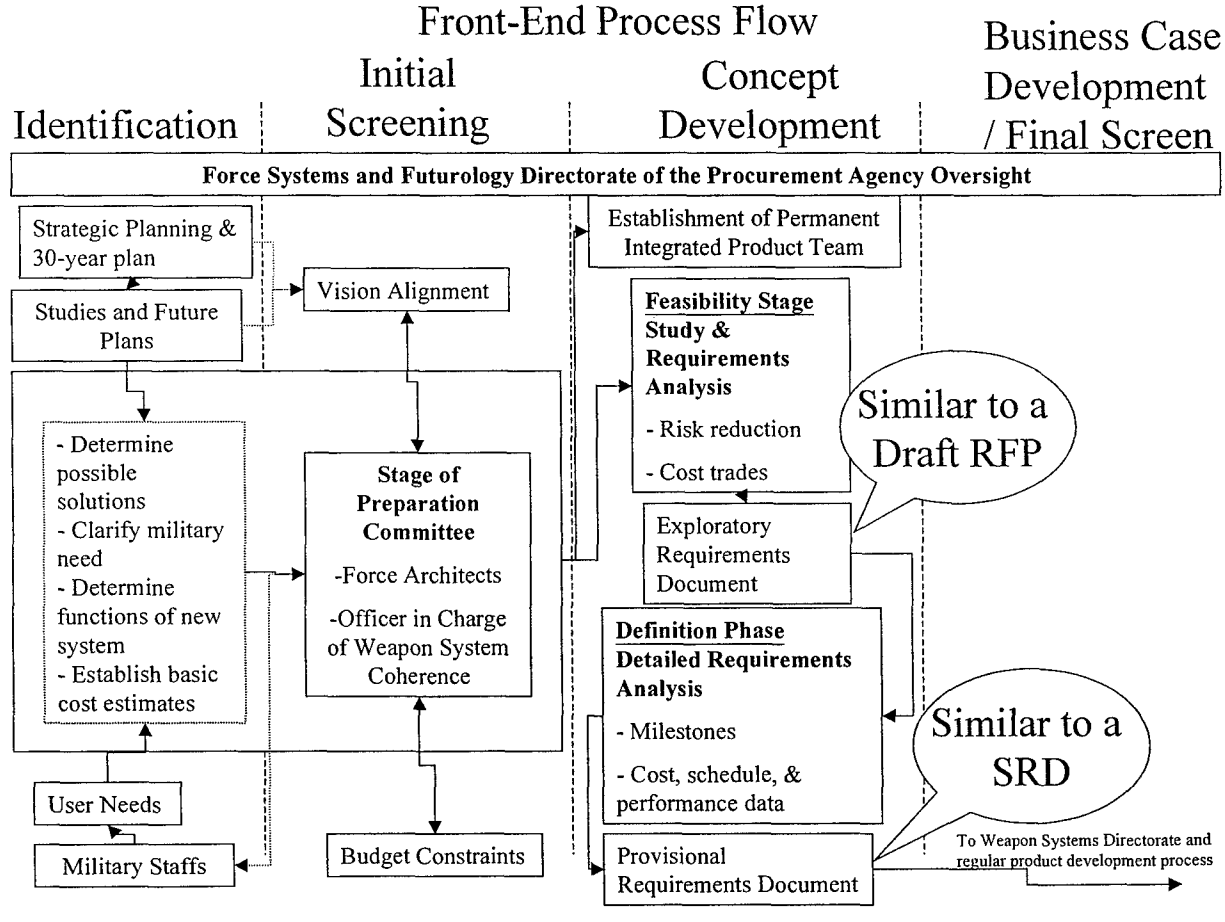


Figure 41. French Front-end Process in Terms of the Framework

Upon the completion of the front-end process and during transition to the other two process owners downstream, a true Business Case is presented. The results of the detailed requirements analysis along with the other studies conducted contain all of the information to complete the business case. Should all the risks be in appropriate ranges, as set by the initial committee, the other directorates immediately launch contract negotiations with the appropriate defense contractor. However, the actual business decision to pursue development of a weapon system takes place with the decision of the Stage of Preparation Committee (during the stage of their process that is most analogous with the Initial Screening phase of the idealized framework). Since the Force Architects, who are members of the committee, are also core personnel within the Force Systems and Futurology Directorate, they have oversight into the overall process. Should instances arise that warrants killing a program before leaving the oversight of the directorate, the Force Architects have the power to do so in conjunction with Operational Concept Officers.

The activities corresponding to the Concept Development phase of the idealized framework suggest much closer working relationships between the acquisition personnel and defense contractors than exist in US Military relationships. The Identification and Initial Screening activities are closest to existing practice within the US Military.

US Military Services

The Three US Military Services are presented below in separate case studies focusing on their respective front-end processes.

Navy Front-end Process

The Navy has a very centralized process for weapon system development. The following diagram illustrates the overall process of the Navy's front-end.

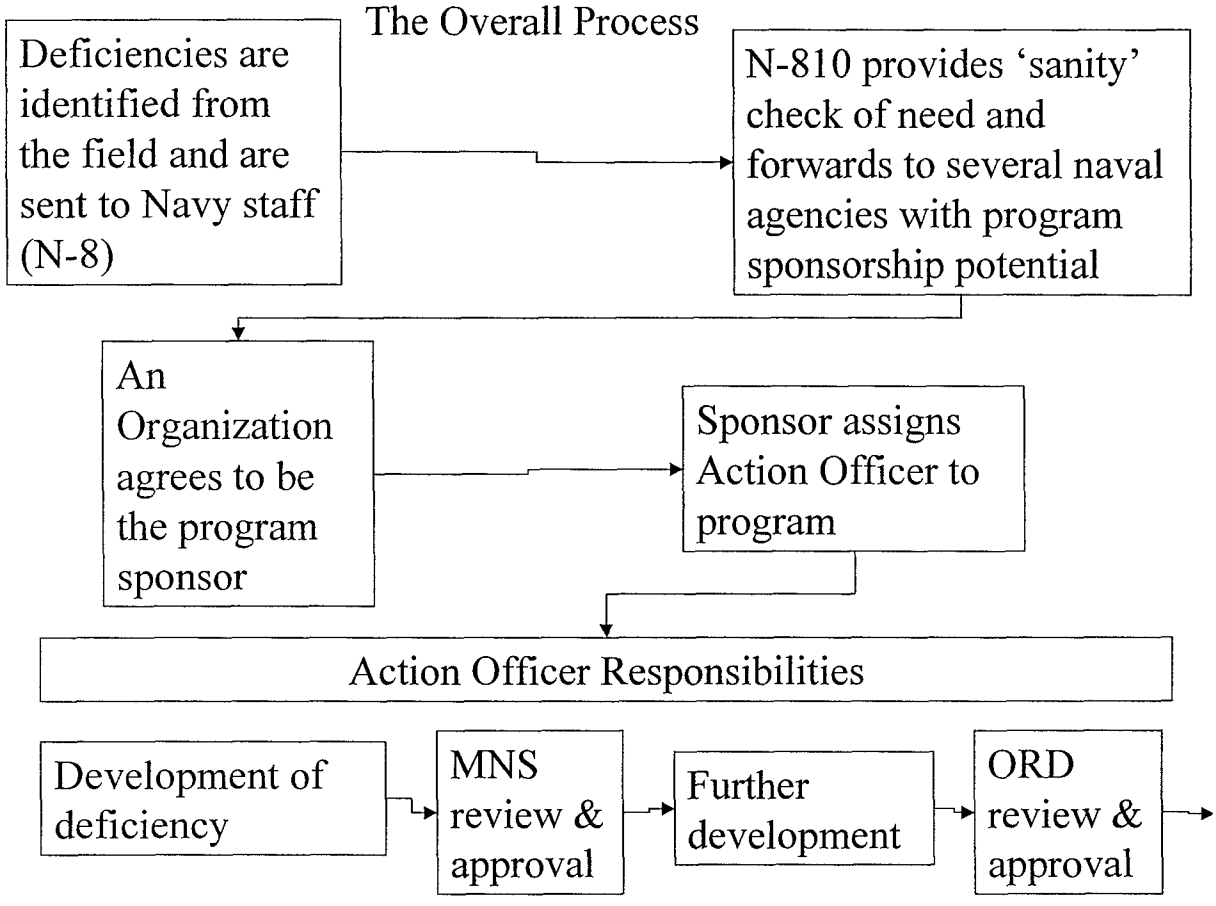


Figure 42. Diagram of the Navy's overall front-end process

The Navy does not have a formalized Strategy to Task environment or anything similar to the Air Force's Modernization Planning Process. However, the Navy does use strategy-to-task, task-to-need, and need-to-solution as the process of choice. The Navy also states that the first choice to solve a deficiency is to do so through a non-materiel solution – mostly for the lower costs involved through such a resolution. If none exists, then a materiel solution is sought. However, according to N8, the greatest source of deficiencies for materiel solutions comes not from the Navy's formalized planning process, rather, the front-end product development process relies upon any source willing to identify a deficiency and exert the effort to document it. Sources of deficiencies can either be top-down or bottom-up generated. Examples of this include exercise debriefs, studies where the Chief of Naval Operations provides an input during the 'out-brief', ACTDs, lab efforts, inputs from the "smart people" in the field, and any other external source (fleets, another sponsor, other services, etc.)

Therefore, the process really begins when someone or some organization sends in a written description of a deficiency. This can be in the form of a Mission Needs Statement draft (the format and regulations are public documents, so any naval personnel can read and follow the format), or another written document.

These documents are sent in to N8[46], the Navy's Deputy Chief of Naval Operations Resources, Warfare Requirements and Assessments division. N83 is the CINC Liaison Division and collects the documents from the fleet. N8 plays a crucial role in the Navy's product development process. It controls 50% of the Navy Staff in the Washington DC area and approximately 75% of the Navy's Total Obligation Authority.

N81, the Assessment Division, conducts a 'screen' on the deficiency to see if it passes the need 'sanity check.' The overall criteria for this screen are based upon the expert judgement of the N81 staff. If the deficiency is judged worthy, N81 will distribute the proposal to the various N8 divisions (and sub elements) to seek a program sponsor. This is an implicit second screening that takes place. Each division as a part of N8 has their own budget and knows its resource constraints as well as a general sense if the deficiency 'fits' in with their overall objectives for their division. If a sponsor doesn't pick up the deficiency, the initiative dies (the deficiency doesn't go away – there just isn't enough interest within the different agencies to pursue its resolution (at that time).)

If an organization decides to pursue a deficiency, that organization becomes the sponsor. The sponsor then becomes responsible for all of the document generation and staffing as well as for the financial support. The sponsoring organization tasks an action officer with the deficiency. That Action Officer is then responsible for the writing of the Mission Needs Statement (MNS), guiding it through the validation and approval stage. If approved, the action officer is given money by the sponsoring organization to do an Analysis of Alternatives. The overall process to get approval for a MNS is approximately 6 months.

[46] N8 has 10 sub-elements (and these each have several sub-elements within them). N80 is the Programming (comptroller) Division. N81 is the Assessment (Analysis) Division. N82 is the Fiscal Management Division. N83 is the CINC Liaison Division. N84 is Anti-Submarine Division. N85 is the Expeditionary Warfare Division. N86 is the Surface Warfare Division. N87 is the Submarine Warfare Division. N88 is the Air Warfare Division. N89 is the Special Programs Division.

An independent analysis group conducts the Analysis of Alternatives (AoA). The overall responsibility for the AoA, although the sponsor is paying for it, is given to the respective Program Element Officer, or other Naval command, to ensure the independent analysis. The AoAs have lengths of variable duration. They can last a couple of weeks or as long as 2 years.

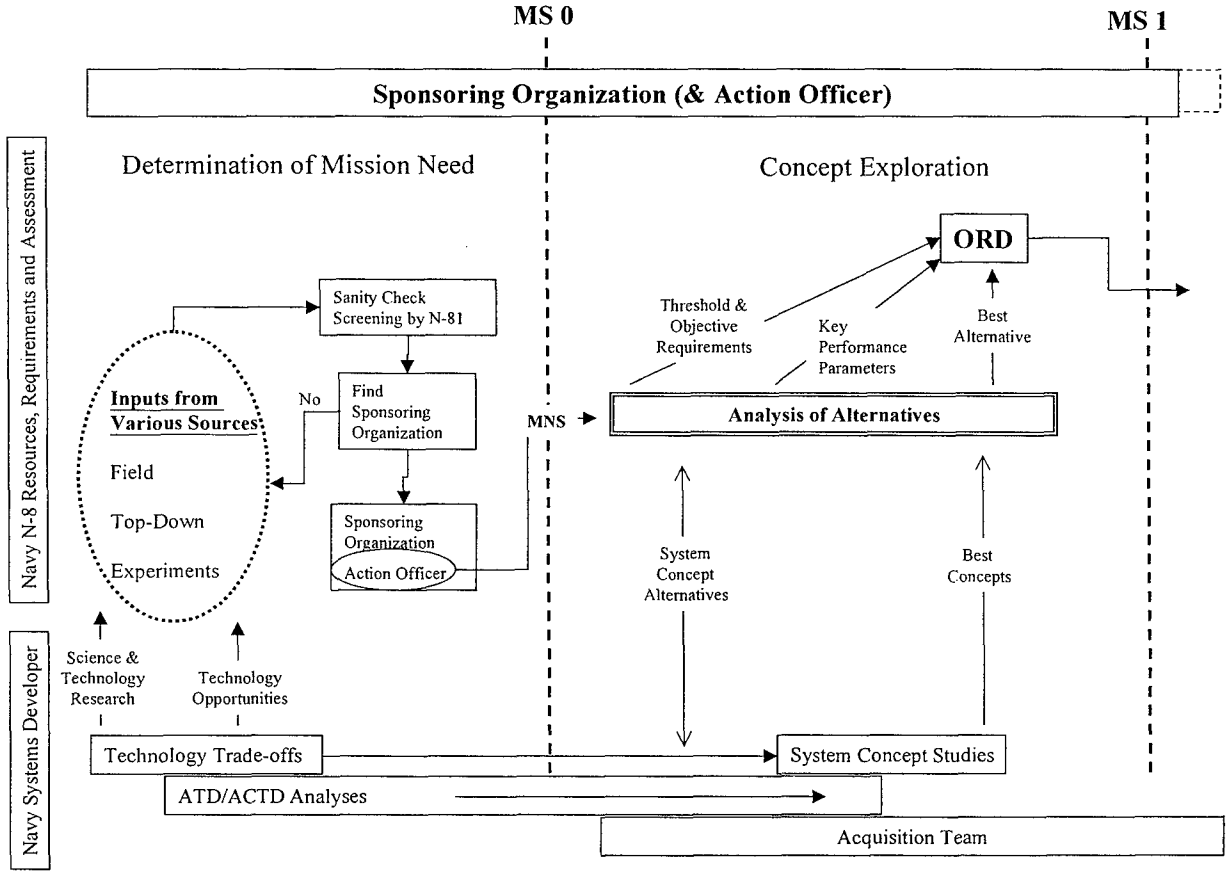


Figure 43. Diagram of the Activities of the Navy's front-end process

As the AoA is being conducted, the Action Officer begins writing the ORD. Pending the results of the AoA, which is the foundation for the KPPs and other threshold and objective requirements listed in the ORD, the ORD validation and approval process begins. The ORD is staffed throughout the Navy for review (the longer the AoA, the more organizations that request a review of the ORD).

The ORD has an initial review cycle outside of the sponsoring organization (which undoubtedly has its own internal review). The cycle has been formally diagramed. An example is found below. There are slightly different variations to this process depending upon the importance and complexity of the project.

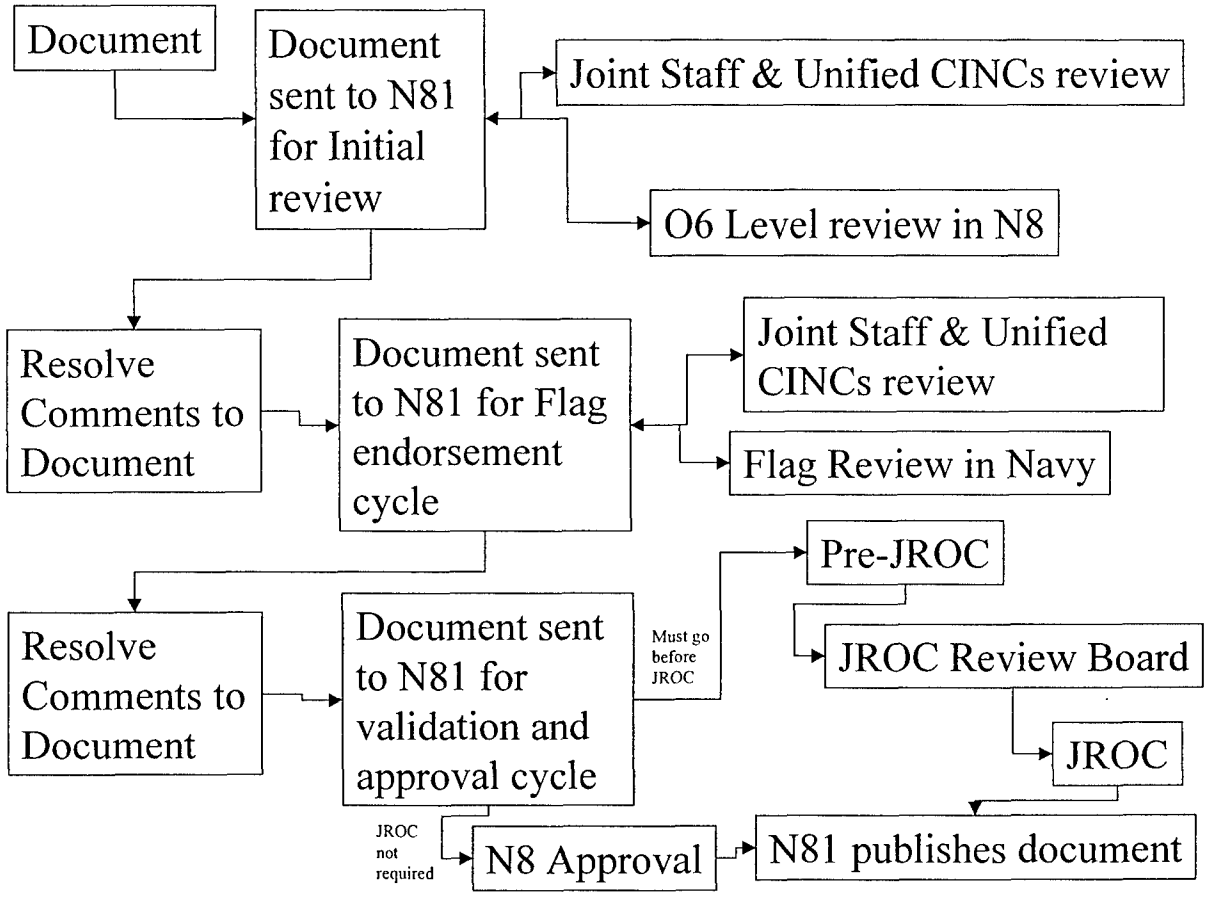


Figure 44. Diagram of the Navy's approval process for needs and requirements

Once the ORD has been approved, the funding process begins. While this is not necessarily done in a serial fashion, it will be depicted in this manner for simplicity. The sponsor takes the ORD and discusses the issue of funding with N80. The sponsor and also N80 will then both go to N8 and recommend that the program be started. It must be fully funded for the program to begin per federal law, (but a liberal interpretation of the law means the program is fully funded if the sponsor

demonstrates they are willing to stand up for the program and put it into the POM.) N-8 then approves the program to go to a Program Element Officer and for acquisition activities to begin.

Organization Issues

The Navy has one 'process' owner, N8, for their Requirements development. However, the actual work is done by one of many sponsoring organizations within N8. N8 also controls most of the Navy's obligation authority and funds for product development, as mentioned earlier. For this reason, different N8 sub-processes control resources (and a budget) along with Requirements development. Nevertheless, another organization, the Assistant Secretary of the Navy, Financial Management & Comptroller division, is responsible for building the Navy's POM and budget.

The use of an Action Officer to shepherd a need or deficiency or requirement through the entire process is a variation on the 'core team' idea. In this case, the sponsoring organization can serve as periphery team members and the Action Officer is the 'team'.

Business Issues

Prioritization of needs and requirements is done at the sponsor level. They decide which need or requirement to pursue when they decide to write the MNS or the ORD. Oftentimes, a committee does this prioritization of needs and requirements. The committee consists of both 'fleet' representatives and N8 members. In the case of Aviation, N88, this group is known as the Air Board. Its members consist of Navy Captain (O-6 rank) members from the fleet who are senior aviators, members of the Naval Aviation Logistics Group and N88 members. This O6 level is where the trades between requirements and resources are made.

N8 uses an Information Technology tool called Link for their Requirements documents, Requirements traceability, and Requirements management. It is another type of requirements management tool that can be easily integrated into the Microsoft Office suite. It also uses a database built upon Microsoft Access to track projects. This tool is fully functional with the Access program.

This liberal interpretation of the funding issue allows sponsoring organizations much more flexibility in their program execution. However, it opens them up to the problem of starting up a lot of programs and then not having the resources available to finish them.

Summary

Overall the Navy addresses each of the different stages of the framework with their process. However, their process does have some unique elements that are worth highlighting.

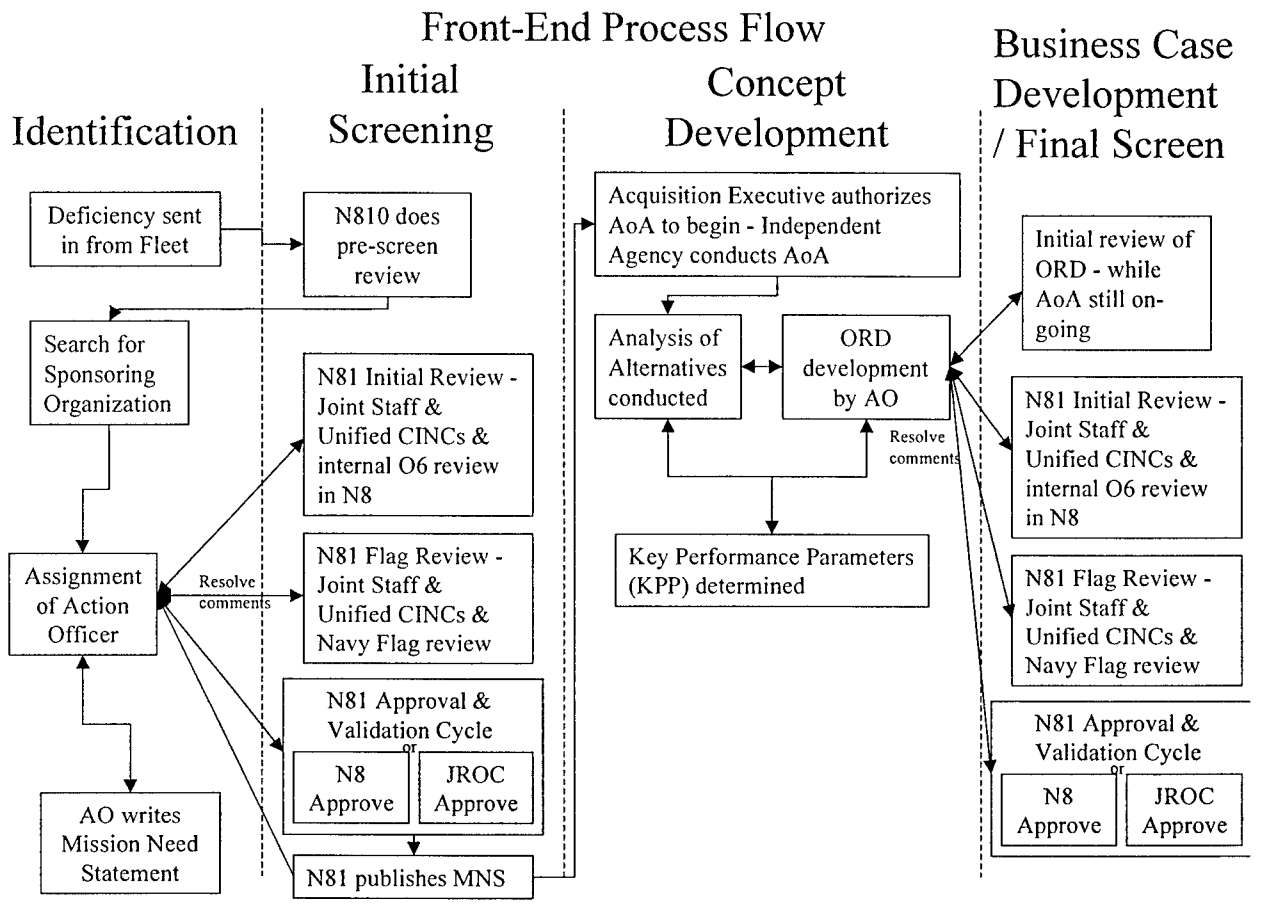


Figure 45. The Navy's Front-end Process in Terms of the Framework

The Navy process contains multiple screens - beyond those mandated by the process instructions of the Joint community. The reasons for this are not clear but the additional screens may be done because most of the resources required for a program are also controlled by the same organization. Another reason for the screens may be due to the distinct lack of end user interaction with the process beyond the initial deficiency identification.

The use of Action Officers throughout the process is a highlight of the process. Although an Action Officer is a team of one, it does not benefit from the idealized framework team composition. Among the key elements missing are cross-functionality and multiple perspectives. Action Officers become the champions of projects even within the sponsoring organization and they are responsible for seeing each project through the system until that project is started with a favorable Milestone I decision. However, it is not known what happens during personnel rotation in and out of the N8 organization and what effect this might have on the status of a project.

The overall time required to navigate the system did not seem to be significantly different from the other military processes examined, except that the Mission Need Statement approval cycle time was about six months (180 days) vs. the longer process of about 400 days in the Air Force.

Army process

The ARMY has a formal front-end process for weapon system development. It is a distributed system spread out between 31 'schools' (organizations that develop doctrine and tactics for specific missions of the Army)[47]. Each school has approximately 25 to 50 people working on the front-end concept development at any given time. The Training and Doctrine Command (TRADOC) is the command responsible for Force Development Requirements Determination. TRADOC has not only the combat developments mission, but also runs the individual training mission. TRADOC manages the major Army installations in the United States housing Army training centers and Army branch schools.

Author's Note: The Army has expressed it is not satisfied with the way their Requirements Process is working. They started an effort in late 1999 to reexamine the way they develop requirements. At this time there is no indication about what changes if any will be made to the process. Some of their concerns are that the decentralized nature of the system is perceived to be 'bad', the process is currently not 'user-friendly', and the current system seems to be too 'stovepiped' given the structure of the schools.

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[47] Air Defense Artillery School, Adjutant General School, Armor School, Army Management Staff College, Aviation Logistics School, Aviation School, Chaplain School, Chemical School, Command and General Staff College, Defense Language Institute Foreign Language Center, Engineer School, Field Artillery School, Finance School, Infantry School, Intelligence School, Logistics Management College, Military Police School, Ordnance Missile and Munitions School, Ordnance School, Quartermaster School, School of the Americas, School of Music, Sergeants Major Academy, Signal School, Soldier Support Institute, Transportation School, Warrant Officer Career Center

The following diagrams show the various aspects of the front-end of the Army. In essence, all requirements are generated at a decentralized level and then fed back up to TRADOC. From this point, the process of MNSs and ORDs follows the standard DoD procedures.

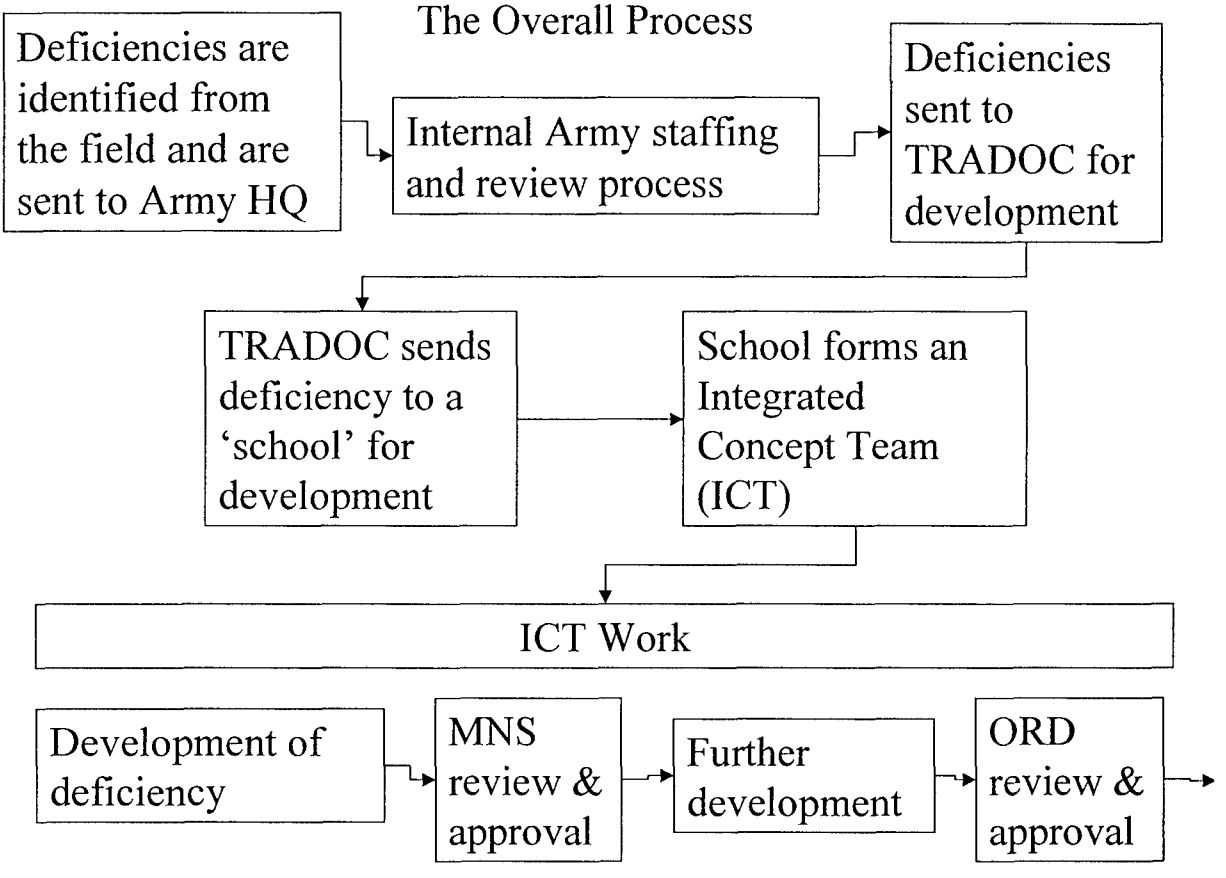

Figure 46. The overall needs and requirements process in the Army from an organizational standpoint

The overall process operates in a fashion usually as described above. The Army Staff at Army Headquarters conducts a screening event before TRADOC gets involved. This ensures that TRADOC stays focused on the Army's mission in its concept development activities. Activities such as technology-push from labs and other sources get their first opportunity to influence product development only at the TRADOC level.

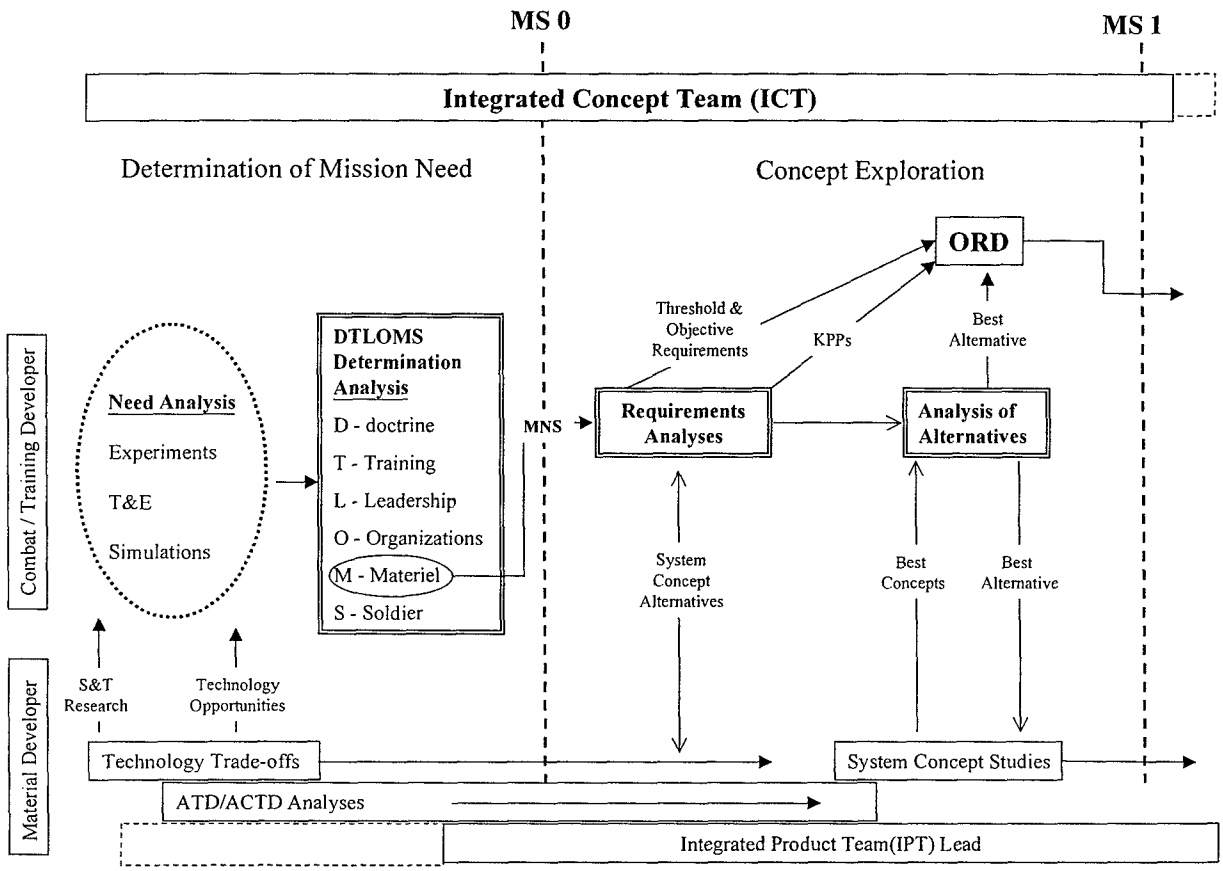

Figure 47. Development of Needs and Requirements in the Army (Adapted from TRADOC Pam 71-9, Figure 9-1)

The material developer in the diagram above is the acquisition community that is kept aware of developments during pre-milestone 0. The combat/training developer shown above is the TRADOC School charged with understanding the need.

An Integrated Concept Team (ICT) is the Army management philosophy and tool for a team approach to requirements generation. It is a multi-disciplinary team that is in charge of the development of user needs and requirements into products such as a Mission Need Statement and an Operational Requirements Document. Team members are empowered to make decisions on behalf of the organizations that they represent. This same team consists of a core group of individuals who are assisted by periphery members as required. The ICT is responsible for the entire process through

Milestone I. As the process prepares to enter the acquisition community, the ICT is assisted by a companion Integrated Product Team (IPT) that assumes more and more responsibility as the process for a material solution goes forward until the IPT assumes full control just after Milestone I in the acquisition process. There are approximately 40 ICTs going on at any given time.

The ICT is charged to pursue Horizontal Requirements Integration (HRI) in the development of mission needs and requirements. HRI is a holistic process that attempts to develop requirements that encompass the entire 'force', not just a particular domain (like tank warfare). To this end, there are two types of ICTs. Tier 1 ICTs are approved and chartered by TRADOC HQ or impact multiple schools or have a high management interest. Tier 2 ICTs are established and run by the school commandants. They look at requirements that have no impact beyond the domain of the school. HRI is not limited to only materiel solutions.

The DTLOMS (Doctrine, Training Leadership, Organizations, Materiel, and Soldier) structure is the method by which the ICT evaluates a mission need. The structure of DTLOMS inplies a hierarchy of importance, as well as one related to the amount of resources required to implement. The further a solution 'goes' along the DTLOMS axis towards 'Soldier', the more expensive it is to correct the mission deficiency and implement a solution. Furthermore, such a solution always has repercussions back up the axis as it impacts everything, including doctrine. Additionally, the ICT must develop solution 'sets' that include near-, mid-, and long-term capabilities for each mission need. Money for the studies and analysis to develop mission needs and requirements comes out of the Army's Operations and Maintenance fund. Most studies and analysis require 1 to 2 years prior to beginning writing requirements documents such as an Operational Requirement Document.

The approval process for these items follows the path indicated below.

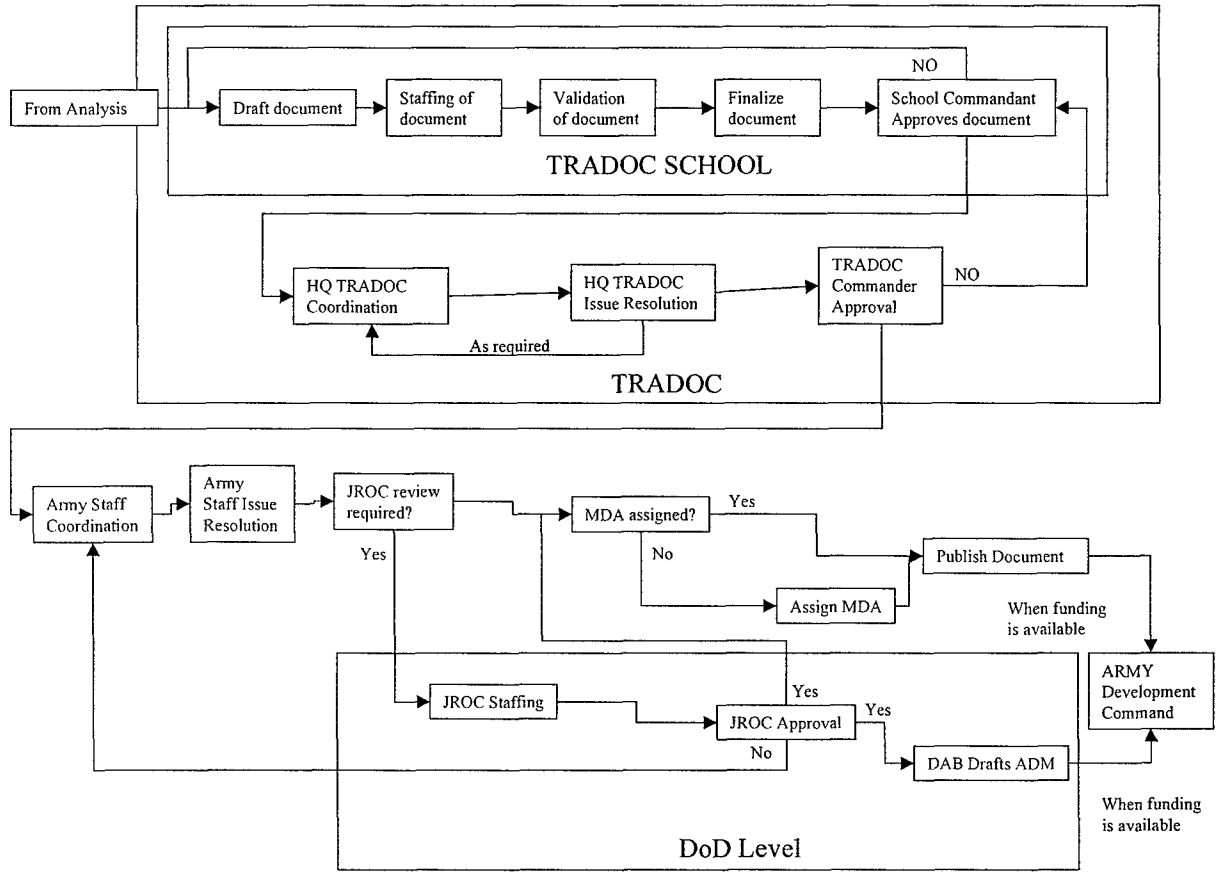

Figure 48. Validation and Approval process in the Army

Any time an ICT develops material requirements that will begin the Army's product development process, the ICT will draft the document. The School's leadership must first approve the document, and then the document is sent to HQ TRADOC. At the HQ, the document is compared and 'harmonized' with any other documents produced by other ICTs from other schools. This means that overlapping requirements are combined, conflicts in mission areas and roles are resolved, and only one requirement in a given area is allowed to proceed. When this is completed and the document is approved by the TRADOC commander, the document is coordinated for review at the Army Staff level in Washington DC before going to the Army Chief of Staff. If the program requires the approval of the JROC, the document then enters a separate process of staffing and review in the joint environment prior to the document's approval. Mission Needs Statements require approximately six

months from the start of the review process to the final approval. Operational Requirements Documents require approximately six months to one year to go through the approval process.

The ICT works on the development of the need and requirement stemming from the deficiency. The core team remains intact and during the review and approval processes for both the MNS and the ORD, so that the team can respond directly to issues that are raised during the process. They also are responsible for the development of the need and requirement through studies and analysis. Because of this, the ICT is well equipped to field questions during the approval process.

The last part of the process is the way product development projects are funded. Funding decisions are done through an entirely different process. This process is essentially the same as the Air Force funding process, which was explained earlier. The method by which the Army Requirements Developers influence the process is called the Warfighting Lens Analysis (WFLA). This is the way TRADOC shows advocacy for a program. Using a methodology similar to a Linear Program, the methodology attempts to prioritize investment decisions for the Army. The WFLA compares the required future capabilities of the Army Total Force against the current fiscal reality. This is used to determine modernization priorities from the point of view of TRADOC. These priorities are established using a methodology that assigns an objective measure of relative value to the mission accomplishment. TRADOC provides WFLA recommendations to Army HQ as key input for the POM (December-odd year) development and, if needed, for the mini-POM (December-even year) development. This process begins approximately one year prior to the PPBS cycle that will build the POM in question. The WFLA process has the potential to change its outcome and priorities every year the analysis is done. Should this occur, the process relies upon the judgement of the decision-makers in this process to note the discrepancies and react accordingly.

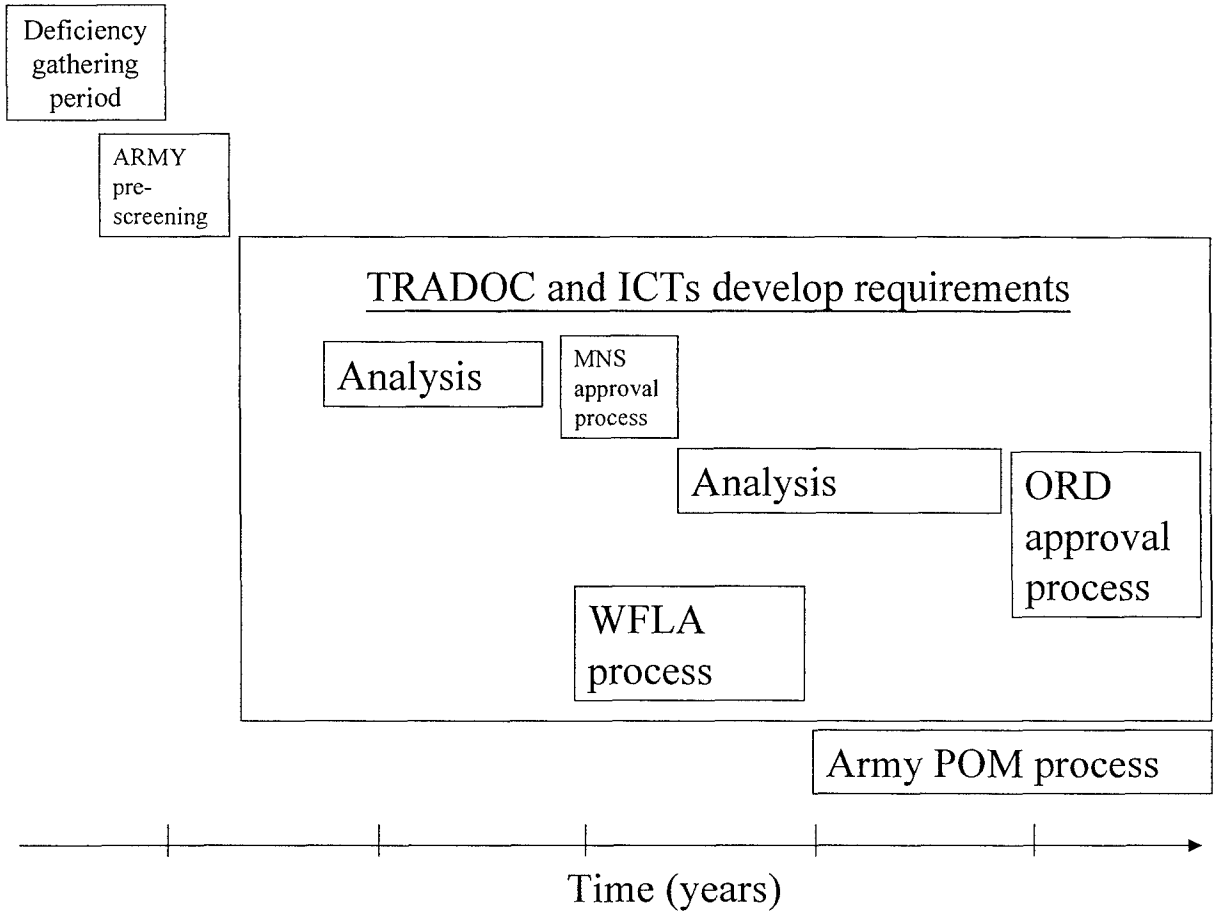

Figure 49. Notional time required navigating the process for needs and requirements in the Army

This diagram shows that if the overall front-end product development process worked perfectly and that those average process times accompanied a deficiency/need/requirement, the process requires six years for a program start to occur. The difficulty in describing these processes serially is that they are constantly changing. This representation implies perfect handoffs between TRADOC and perfectly getting program requirements into the POM process. The diagram also assumes that the first time a MNS is approved that it will make it into the next POM. The diagram also assumes there are no politically charged issues with the requirement that might delay the process outcome. This does not always occur. Intuitively, if some of the firm dates to participate in the resourcing process are missed, another year is potentially added to the process. It is also clear that delays in any of the processes

invariably lengthen an already long front-end process. Additionally, this process flow is very complicated in that it is continuous. For instance, this diagram really should contain the overlapping processes of the six years worth of POM building that would occur on this time line.

The various Army Commands are not prohibited from developing concepts and ideas on their own and to field and deploy them. However, should a decision to do so be reached, that Major Command is then obligated to be responsible for all training, education, doctrine, maintenance, and support of that equipment. Because of these reasons, this approach is rarely used.

According to the Army, within the 'normal' system, there is a pervasive atmosphere today of not spending money on a program unless the Army is absolutely sure that it is worth it. Therefore, a lot more analysis and experimentation is done than ever before.

There are other processes that exist to 'shorten' the process or take advantage of new technologies, etc. These are funded under special programs like the WRAP (Warfighter Rapid Acquisition Program) of the Soldier Enhancement Program. Most of the shortening that occurs is only in the review and prioritization processes – not the analyses or other background work the ICT normally does.

Organizational Issues

The Army Requirements Process could be compared to an hourglass. At the top level, items for discussion can come in from anywhere. They all must go through the Army HQ Staff and TRADOC and then TRADOC distributes all of the work out through the 31 schools it operates. Then, as the ICTs converge on a 'solution', then they must go again through TRADOC (the neck of the hourglass) and then go up to the Army staff and are distributed throughout the Pentagon and Joint community for further validation and approval actions.

The ICT is a unique expression of a military team developing requirements from the initial part of the fuzzy front-end of the process all the way through Milestone I, where it is transitioned to an IPT of acquisition professionals. Organizationally, the ICT makes binding decisions for the Army organizations they represent, although they are operated within the schools of TRADOC.

Business Issues

The use of the DTLOMS method in defining deficiencies and developing needs and requirements from them comprises an integrated look at all of the components of the 'business' of the Army. Strategically, this method is critical so that the focus of product development within the Army remains tuned to the roles and mission of the Army.

Like the Air Force, the Army has a separate method to allocate and prioritize resources. This system is very formalized and requires a lot of effort to obtain the desired outcome – funding the needs of the Army. The business case for potential product development projects is constructed by the ICT and documented in the MNS and ORD. However, there is no organization within the Army that approves a 'business case'. These are split into two separate actions – the Army Requirements Approval Process and the WFLA process. The ICT only submits information to the WFLA process. The ICT does not control it nor maintain it (however, the WFLA process is owned by an organization within TRADOC).

Summary

The Army process contains several elements of the idealized framework. Among the more interesting items is the existence of the ICT, the holistic look of how a need or deficiency fits into the strategic aims of the organization (the Army) and the use of quantitative tools to develop a prioritized list of requirements. Also of note is the sophisticated use of modeling and simulation at this early stage. Additionally, allowing the ICT to determine which type of development path a need or requirement should take (i.e. ATD, ACTD, Experiments, and Battlelabs) shows remarkable trust in the ICT process.

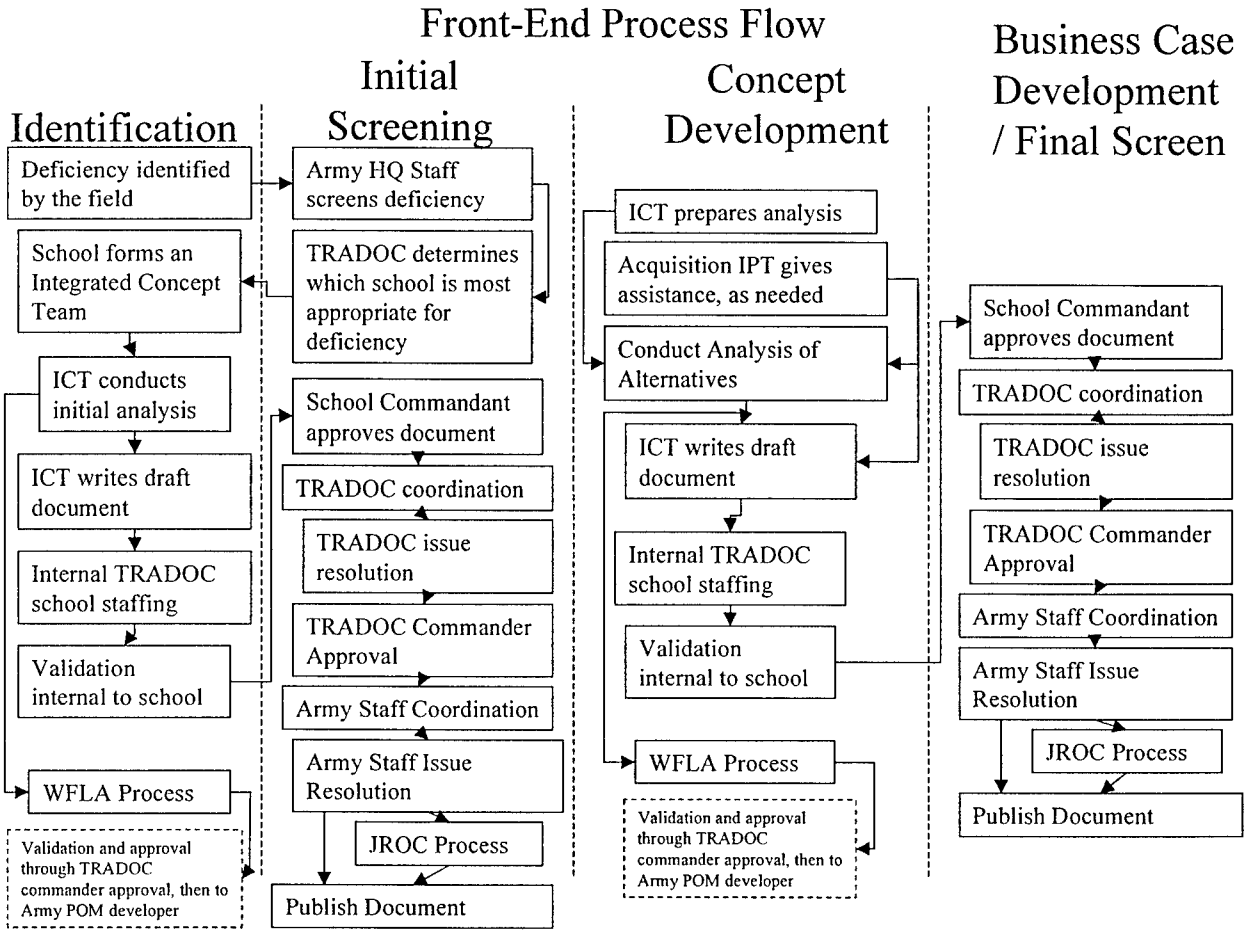

Figure 50. Army's Front-end Process in Terms of the Framework

Nevertheless, a review of the process in light of the idealized framework seems to indicate a lack of trust among the different organizations (each one needing to coordinate and validate the work of the ICT before releasing it to the next higher organizational level within the Army). This becomes a process of "checkers checking the work of the checkers." Furthermore, the process seems disconnected between the development of needs and requirements and the budgeting and funding of those needs and requirements. It is not clear that the process is integrated between these items.

Marine Corps process

The Marine Corps has a formalized front-end process as a part of its product development process. Its focus is to produce integrated capabilities for the Marine Corps. The Marine Corps Combat Development Command (MCCDC) is responsible for the process. The Commanding General of the

MCCDC is a 3 star officer that is the executive agent to the Commandant of the Marine Corps for Combat Development.

Author's Note: Recent changes to the process have been announced. The Assistant Commandant of the Marine Corps (ACMC) will now approve all Requirements Documents for the Marine Corps. It is not clear whether the ACMC has assumed chairmanship of the CAC or if another forum for review has been organized at the Pentagon.

A Capabilities Assessment Council (CAC) controls the Marine Corps front-end process. The CAC is the senior decision making body for DOTES (Doctrine, Organization, Training and education, Equipment, and Support and facilities) assessments. These assessments are done to help make the hard decisions between current deficiencies and future requirements. The CAC meets on a quarterly basis and includes membership from all process owners as well as Marine Expeditionary Forces and other marine forces. The members are Colonels and the Deputy Commanding General, MCCDC (2-star officer), chairs the committee. Additionally, there is a CAC Working Group (CAWG) that reviews all Future Marine Force (FMF) Operational Need Statements (FONS). Potential FONS and other deficiencies are initially submitted to the Requirements Division of the Warfighting Development Integration Division (WDID) and MCCDC for review and action by the operating forces. In addition to the FONS, there are other sources of information seeking entrance to the Marine Corps front-end process. Some of the sources are National Military Strategy, CINC's Integrated Priority Lists, Experimental results, Marine Corps Master Plan, Wargames, Mission Area Analyses (MAAs), Advanced concept Technology Demonstrations (ACTDs), Defense Science Board, Marine Corps Lessons Learned System, etc.

The overall process is presented below.

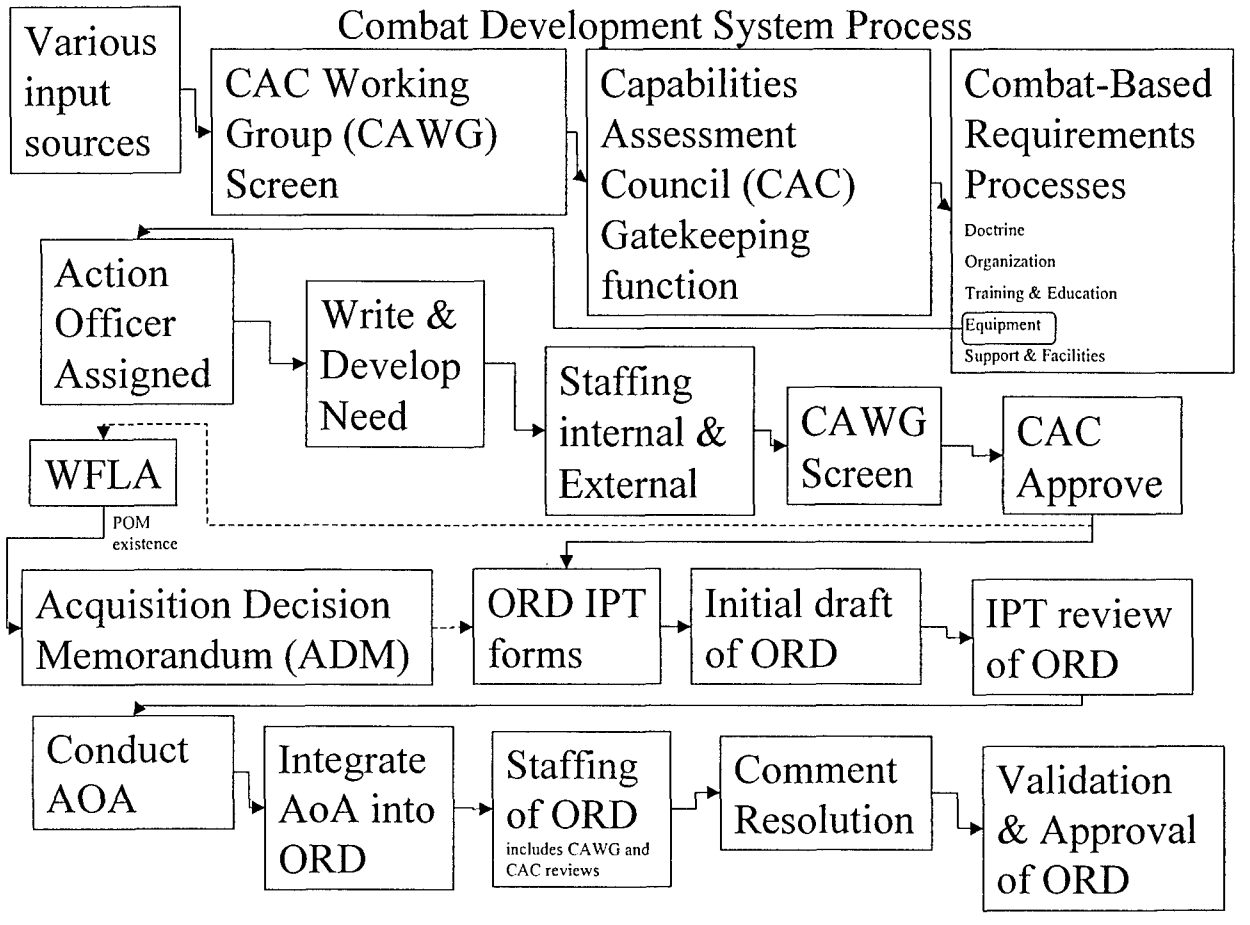

Figure 51. Diagram of Process Flow for Marine Corps front-end process

One organization within the MCCDC, WDID, is responsible for most of the front-end activities. WDID takes a holistic view of needs and requirements by using the DOTES framework. The 'Equipment' portion of the framework primarily addresses Requirements and Material needs, but any new need or requirement impacts all of the other elements of the framework. By acknowledging this, the Marine Corps hopes to produce integrated capabilities for the Marine Corps.

The Marine Corps has eight core processes. These are Concept Based Requirements, Resource Allocation, Total Force Structure, Human Resource Development, Material Lifecycle Management, Infrastructure Management, Information Management, and Service Advocacy. WDID is responsible for integration across both Functional Areas and Processes. The following diagram illustrates the Concept-Based Requirements Process through which all the processes are impacted.

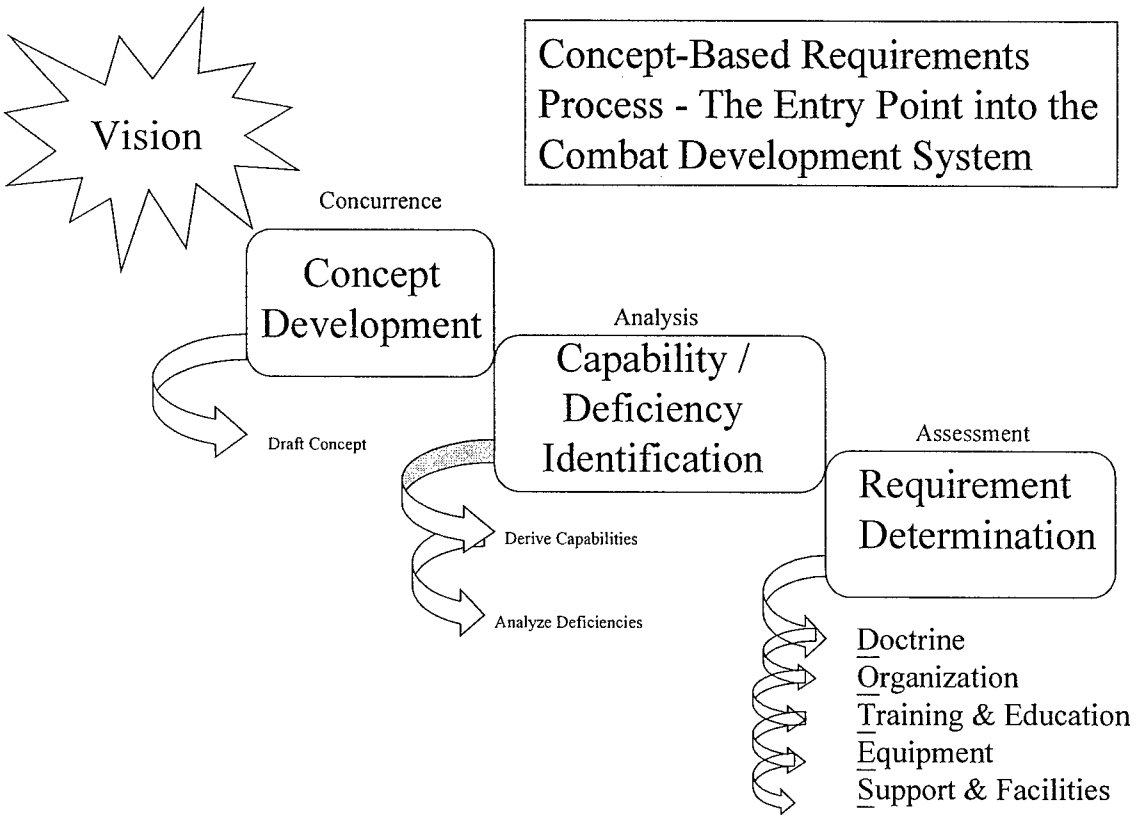

Figure 52. Diagram of the Concept-Based Requirements Process Flow

The WDID Requirements Division, as mentioned earlier, is the focal point where all initial requirements documents (like a FONS) are collected for evaluation by the Concept Development System. Upon receipt of a potential FONS, or upon the decision of the CAC that a deficiency identified by other means requires a material solution, the Requirements Division assigns an Action Officer to write and develop the FONS. This Action Officer staffs the FONS to various MCCDC and Headquarters Marine Corps (HQMC) agencies for review and comments. (Unfortunately, the review and comment process can introduce excessive or indefinite delays into the overall process. This can occur at any of the several review stages that exist within the process as well.) Once all comments have been resolved, the FONS is screened by the CAWG. Pending no issues that require further resolution, the FONS is reviewed by the CAC. An approved FONS is prioritized into the MCCDC Priority List that is submitted to the POM Working Group (PWG) for consideration. The

process by which the FONS is prioritized is nearly identical to the method used by the Army. The Marine Corps has a division that also reports directly to the Commanding General MCCDC called the Warfighting Lens Division. This division conducts the Warfighting Lens Analysis on all needs and requirements.

Should the FONS be programmed into the budget, the preparations for ORD development begin. There are 9 steps in this process. The first action is the issuance of an Acquisition Decision Memorandum. This document indicates that money is available to begin work on the FONS and also names the Program Manager for the Acquisition Portion of the effort.

The second action that occurs is the development of the ORD Integrated Product Team (IPT). The IPT members are permanent. They remain part of the team throughout the life of the program and the various ORD iterations that occur during the different acquisition phases. There are three core members on the IPT. The first member is from MCCDC and is called the 'Requirements Officer (RO)'. The second core team member is from the Marine Corps Acquisition Corps and is called the 'Project Officer (PO)'. This person is not the Program Manager, but acts as a liaison between the program manager and the ORD IPT. The third core team member is from the Marine Corps Operational Test and Evaluation Division and is called the 'Operational Test Project Officer (OTPO)'. Other team members from other organizations are added as required. The Requirements Officer chairs the IPT.

The third step is for the Requirements Officer to produce an initial draft of the ORD that is as specific as possible. He identifies preliminary issues and Key Performance Parameters (KPPs) as much as possible. Many items are likely to be left unspecified at this early stage in the ORD development.

The fourth step is where the IPT reviews the ORD and makes a recommendation for an Analysis of Alternatives or a Request for Alternative Approval (ATDs, ACTDs, etc.). There are specific criteria that identify which route of analysis is most appropriate.

The fifth step is to conduct the AoA. These are of varying complexity and length. The alternative approval route puts the initiative into different processes. Upon completion, (of an ACTD for instance), an ORD has to be written based upon the outcome of the alternative processes.

The sixth step is to integrate the analysis of the AoA and other analyses into the ORD. The ORD is refined so that defendable rationale exists throughout the document. Additionally, two additional appendices to the ORD are created. The first one is a dendritic map that shows the relationship of all of the requirements to the different communities (the user, the acquirer, and the tester). The second appendix gives the requirements history and rationale.

At this point (the seventh step), the ORD is ready for staffing throughout the Marine Corps and other services. Internally, the ORD goes through the CAWG, and then the CAC to ensure that they support the current doctrine, adhere to the approved standards, and architectures, and comply with the existing planning guidance. Usually this process both internally and externally is about 45 days long.

After the staffing, the IPT must resolve all comments that have been received (during this eighth step). Upon resolution of those comments (and the unspecified time to resolve the comments), the IPT submits the ORD for approval to the Commanding General, MCCDC. With the CGs validation, it is forwarded to the Assistant Commandant of the Marine Corps (ACMC), who approves the ORD (the ninth step). If there is Joint interest in this ORD, it must be approved by the Joint Requirements Oversight Committee (JROC). The process for the JROC has been elaborated upon in other case studies. The major change to the process is that a few more review layers are added to the process, and also the ACMC validates the ORD as the Marine Corps position and the JROC will approve it.

Organizational Issues

The Marine Corps uses the CAC as the gatekeeper to the front-end of the Marine Corps process. Overall the front-end process consists of several screens prior to a Milestone I decision. There are at least six screening functions prior to the approval stage or prior to entering the 'joint' environment. Not all of these screens are explicit. The POM development process also acts as an implicit screen as well.

With the exception of resources, the entire front-end process is located within one organization. The notion of integration across all of the different processes and functions is instilled within the organization. This is expressed not only in the organizational design of their process, but with the assignment of one Action Officer to develop the FONS and a core IPT to develop the ORD.

Business Issues

Resource Allocation is kept separate from the Combat Development Organization. The CDC simply has input into the POM building process through the WFLA. The PPBS of the Marine Corps has to make the prioritization decisions on which new development programs to fund and how to interpret the information advocated by the WFLA output.

Overall strategy of the Marine Corps has been distilled throughout the organization through their DOTES framework and impacts all areas of their decision making process. It is not clear that the POM process reflects the holistic view the DOTES process forces on the front-end development activities.

Summary

Overall, the Marine Corps front-end process contains most of the elements of the idealized front-end process, however it is not idealistic. Their process can be characterized as one with multiple screens and one with disconnects between the weapon system development process and the resourcing process. This separation is a distinct disadvantage.

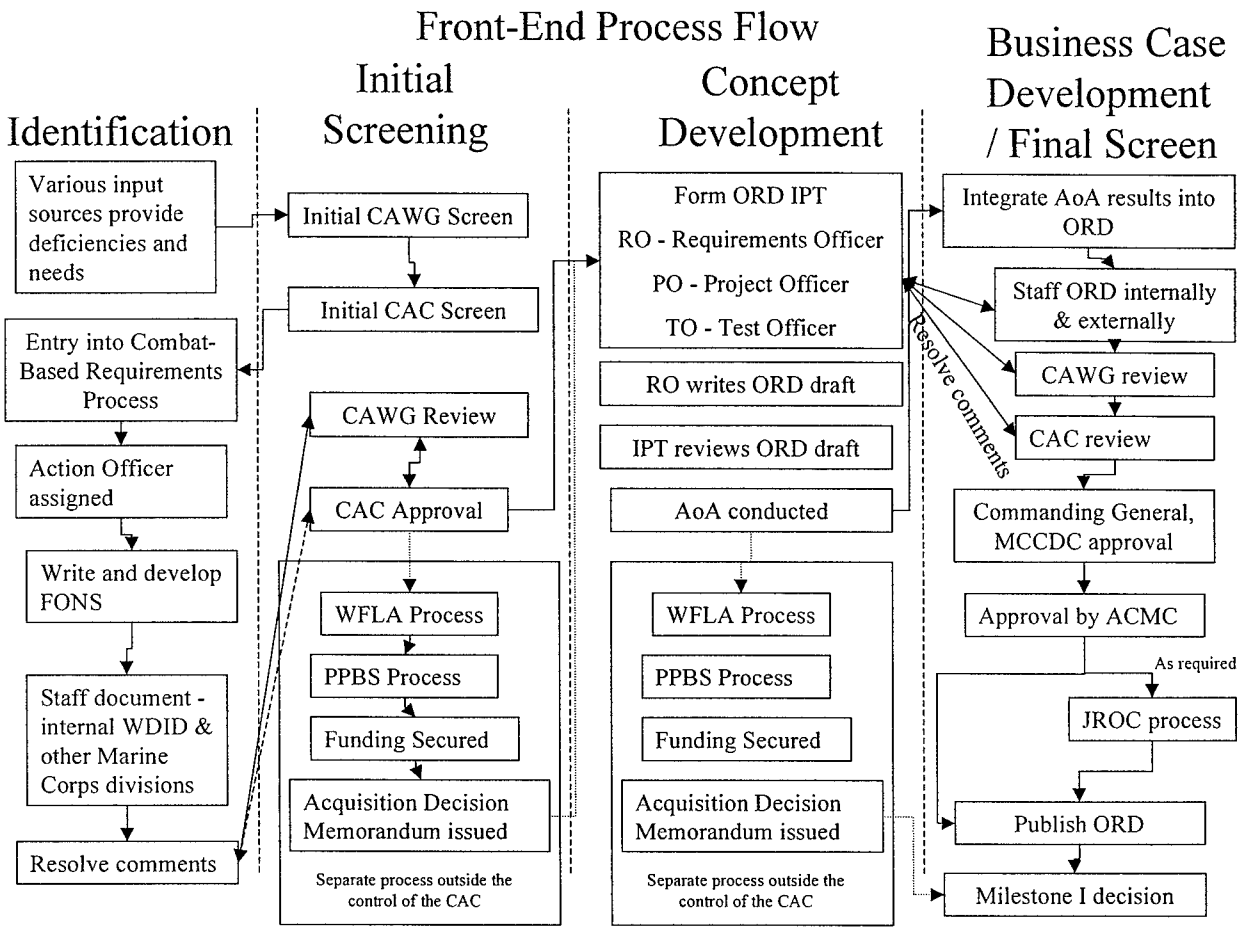

Figure 53. Marine Corps Front-end in Terms of the Framework

The Corps' front-end process recognizes the importance of holistic thinking and the approach toward integrative capabilities for the entire Marine Corps. Using Action Officers and the Core IPT approaches for developing the need statements and requirements documents is a positive step. However, the process is open to multiple review stages where comment resolution can delay the process excessively or indefinitely.

Additionally, the Marine Corps process targets in advance the kind of solution that is preferred. This happens by writing a draft ORD prior to conducting the AoA. By so doing, the AoA can be effectively tailored so as to favor the preferred outcome from the very beginning.

Unified Commands

These additional case studies represent special cases in Requirements Development. One organization is allowed to pursue product development programs under its own authority. It represents a microcosm of the other larger product development processes of the other services. The remaining three cases represent only a portion of the front-end of product development. These three cases share an analog with those companies that are primarily end users of another company's products, although their organizations are vastly different from each other as well as the missions they perform.

US Special Operations Command

This organization is a joint command consisting of different service counterparts. It is unique in that this command has its own PPBS process and budgeting authority entirely separate from the other elements of the US Military and have a Total Obligation Authority of about $3.3 Billion. About 25% ($600M per year) of that is for modernization – and is shrinking every year. The modernization account is the one used to also pay for contingencies that have not been budgeted for.

The process used by this organization is called the Strategic Planning Process (SPP). It includes the PPBS, Requirements Generation, and interfaces with Acquisition. This organization developed after a critical process review found that the overall system contained problems with guidance, integration, process discipline, and analysis.

The Materiel Requirements Process is the US SOCOM process to deal with requirements generation and validation. Foremost, the warfighter/commands identify the deficiencies. As inputs, the commands use information derived from the Strategic Planning Process guidance, Mission Area Analyses, Capabilities Assessments, and Operational Activities. One organization at this unified command validates requirements. US SOCOM does conduct some Future Concept Working Groups (FCWG) and also does some Long-range Planning that the components (the different service counterparts that comprise USSOCCOM) can use as inputs to their front-end processes (an example of this is the Integrated Priority List (IPL) USSOCOM creates every year).

The individual service components conduct their own front-end processes. This includes the identification of deficiencies. The actual writing of Requirements documents is done within the

component command's organization. It is also staffed within the command for comments and resolution before it gets to US SOCOM. The following diagram illustrates the process.

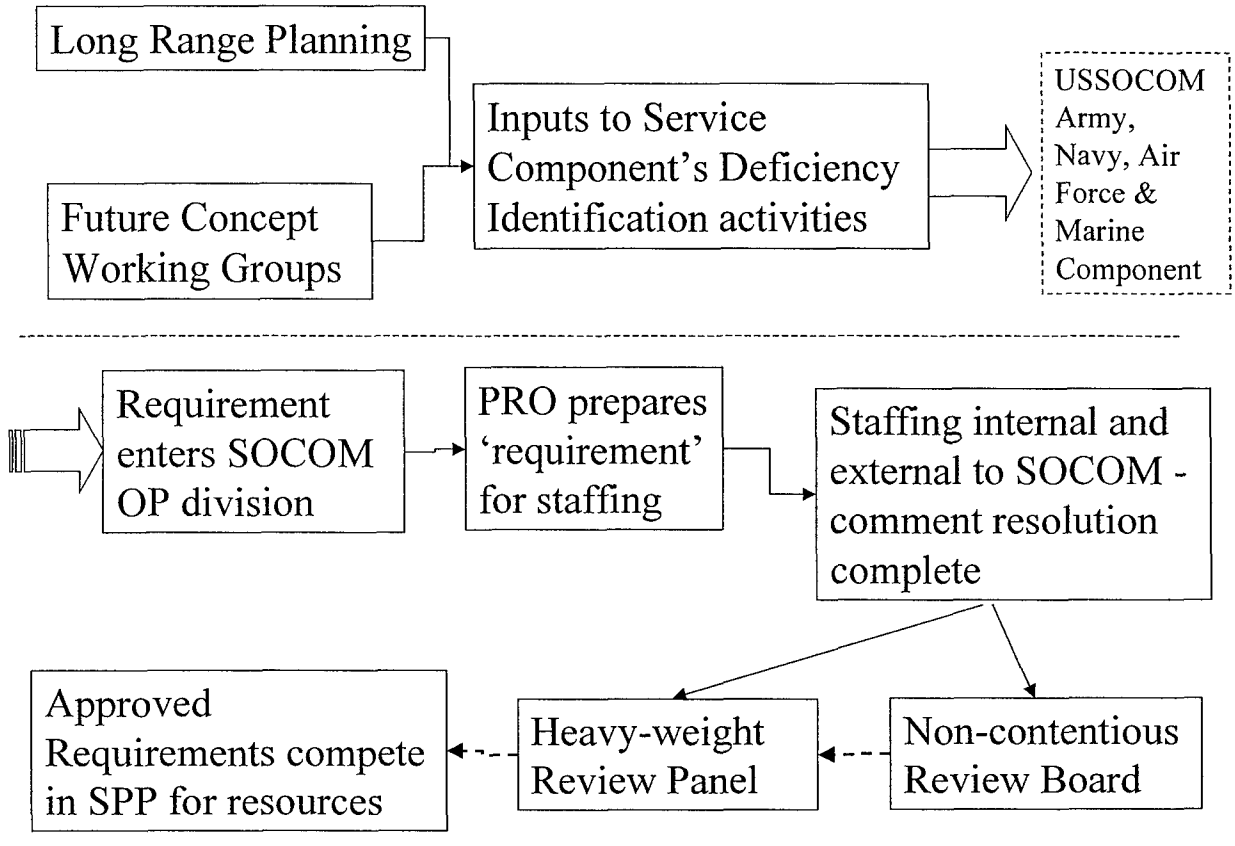

Figure 54. US SOCOM Requirements Generation Process Flow Chart

When a document is received at US SOCOM, the organization responsible for Requirements Documents is the Operations and Plans (OP) division. OP will assign one of about 13 Program Requirements Officers (PROs) to the document. That individual is responsible to see that the document is staffed for 'clarity of deficiency', 'level of required analysis', and 'fidelity of solution.' One of the first screens used is that of 'joint potential' (i.e. the potential of this requirement to be valid for more than one service). If a document indicates this is the case, it must be staffed to the other component commands as well as the other services outside of SOCOM. Once all comments are gathered and resolved, the PRO takes the document to either one of two approval boards – depending

upon the contentious nature of the effort. A document that does not have a lot of 'attention' or baggage attached to it will go before a board (of 5 one-star officers). They meet only as required – if there are enough documents queued up as to make a meeting worthwhile. More politically charged documents go before a higher level board (three-star officers) at which the decision is made.

This organization has about 40 to 60 documents a year traverse the system (vs. the entire Air Force's 100 or so documents). Some can get through the validation phase within 30 days. Those that are politically charged can take much longer – sometimes years. However, having a Validated document doesn't mean there is any money involved. It just means that US SOCOM has defined a deficiency and/or an Operational Need. Mission Need Statements (MNS) require approximately 30 to 60 days to get through the process (99% get through in 30 days). Operational Requirement Documents (ORD) require anywhere from 30 to 60 days.

Validated documents are approved once a year by an annual evaluation of the SOCOM General Officer/Fleet Officer commanding the SOCOM. This is the closest point US SOCOM gets to a true Business Case Decision Forum. Decisions are made with some sense of the cost and urgency attached to each document, however, resources decisions are not made in this forum. Following approval, all requirements compete within the Strategic Planning Process (SPP) for funding. The Prioritization and funding of requirements is determined during the Capability and Program Assessment Phases of the SPP. There are five different assessment areas that the document could be evaluated in (e.g. strike, engage, support, C4I, mobility). The most appropriate one is chosen. Then, all requirements in these assessment areas are evaluated and prioritized based upon extensive modeling and simulation. Integrated Concept Teams (ICT) evaluate the modeling and simulation results. These teams use mathematically driven scoring (QFD) to build the rack and stack list. Of course, these lists are always subject to 'override authority' by their bosses.

The Program Objective Memorandum (POM) is built based upon the rack and stack lists that are created. The five different assessment area directors must work together to build the overall SOCOM prioritized list and with the POM builders in the SPP.

Generally speaking, only about 10% (4 to 6) of documents in any given year are funded. However, this is not seen as a poor thing by the warfighter. Rather, the CINCs would rather have an approved

document that can be 'activated' at any time in case money breaks free (end of year fallout money, etc.). Currently, there are about 200 to 250 approved Requirements documents that are awaiting action. These approved (but deferred) documents are reviewed on an annual basis or whenever the PRO is changed to verify the requirement is still valid.

When a requirements document is funded, the funding includes the entire projected funding stream from Phase 0 activities to retirement of a system. The funds are dispersed to the service components according to the type of system development that will be going on. Therefore, the funding for a system includes resources for an Analysis of Alternatives (AoA) from the very beginning. Mostly contractors with SOMCOM oversight conduct these AoAs. The service component has a much more active role with the AoA contractor mostly because the service component is responsible for dispersing the money. The component command uses the results of the AoA to prepare the ORD for SOCOM validation and approval. The AoA is considered to be one of the key studies in preparing the initial ORD.

In order to spend money allocated to a system development project, the USSOCOM Acquisition Executive must release an Acquisition Decision Memorandum (ADM). This is the same kind of ADM that each of the services use. The ADM references the applicable requirement document as being validated and approved by the proper authority and also certifies that money has been allocated and is available for the system development. The same process is used at each milestone, whether for a Mission Need Statement or for an Operational Requirements Document.

Additionally, as USSOCOM is a unified command, it is required to submit an Integrated Priority List (IPL) to the JROC. Also, USSOCOM may use the Joint Warfighter Capabilities Assessment (JWCA) process to try to obtain the resources necessary purchase or fund any requirement that outstrips USSOCOM's resources.

Organizational Issues

The SOCOM process is conducted by a small group of people working together. The small numbers of people the PROs need to know at the service component level facilitates some of the organizational functioning. The process flows much more smoothly, according to USSOCOM, because of the small organizational size.

There are two distinct processes that are required to agree in order for a requirement to be able to receive funding for further development, the Materiel Requirements Process and the Strategic Planning Process. These processes operate independently of one another.

Business Issues

According to USSOCOM, Mission Area Plans developed by the service components seem to be disconnected from the overall priorities of USSOCOM. The Mission Area Plans (MAPs) of the different service components do not directly correlate to the five capability assessment areas SOCOM uses. MAPs tend to be built along service 'core competencies' and don't translate easily to the SOCOM categories.

They currently do not have a single IT solution to track requirements. They are awaiting the approval of IRSS and are currently using a variation of Excel databases, Access databases, and paper tracking mechanisms.

USSOCOM is also willing to accept money/resources from any service that wishes to participate in a development project. This brings additional resources to the project that it otherwise wouldn't receive. This allows SOCOM to leverage the resources that are added to the SOCOM resources to pursue other SOCOM priorities. However, these additional resources are funneled directly to the individual service component rather than to USSOCOM for distribution.

Summary

This organization is a microcosm of the US defense department. Each service component conducts the front-end portion of the process, to include the derivation of needs and the building of the initial requirements document (MNS). From this organization's perspective, the individual services vary in their ability to identify deficiencies. This variability manifests itself during a requirement document review. Some documents are better written than others are and this variation seems to vary largely by service.

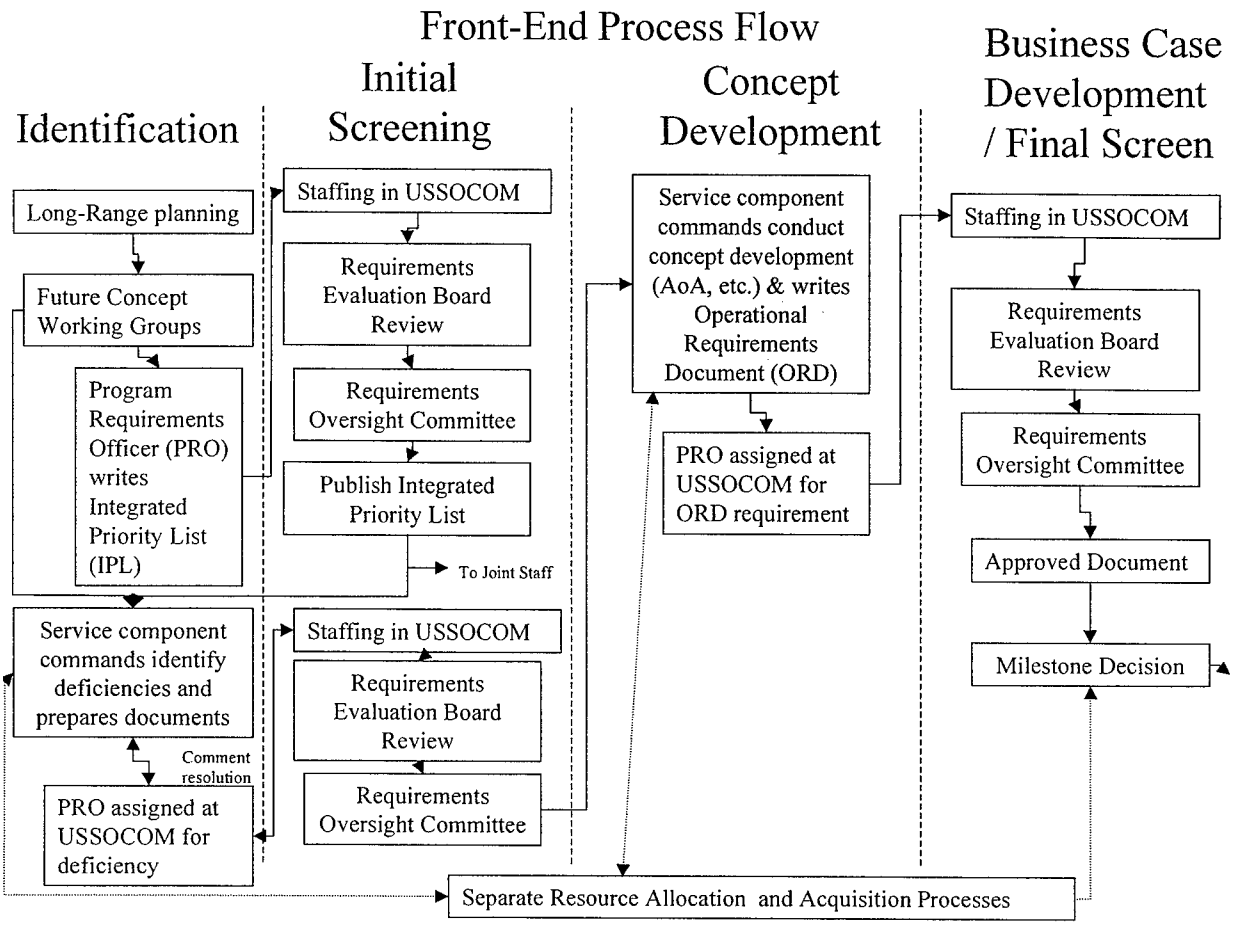

Figure 55. US SOCOM's Front-end in Terms of the Framework

US Joint Forces Command Process View

USJFCOM used to be known as ACOM, or the Atlantic Command. This changed in 1998 when it was renamed the US Joint Forces Command. This is a joint service command (one of nine) with Headquarters in Norfolk VA. There are five joint commands with Geographic Areas of Responsibility (such as the Atlantic area) and four with Functional Areas of Responsibility (such as Special Operations and Space Assets.) In early 1999, the USJFCOM commander was deputized by the other joint warfighting commanders to act as THE advocate for Requirements Issues to the DoD (CJCS 1999). USJFCOM is to be the "Chief Advocate of Jointness". It has assumed the role of America's joint force integrator, trainer and provider; and architect for the future of America's military.

Recent modifications to the Title X statutes, particularly through the Goldwater-Nichols reforms, named the Chairman of the Joint Chiefs of Staff responsible to prioritize a list of needs and requirements. This legislation has since been interpreted to mean that the Joint Commanders should put together a priority list and send these to the appropriate service component commanders (such as ACC or N8 or MCCDC) so that they pursue the appropriate system development. This list is known as the Integrated Priority List or IPL.

The process to build the IPL is shown graphically in the diagram below. The process follows in this fashion: some time in July, the DoD sends out guidance to the joint command Commander - in - Chiefs (CINCs) on how to build the IPL. USJFCOM sends the same message out to its different service component commanders (within USJFCOM) almost immediately afterward. The final IPL is published in December.

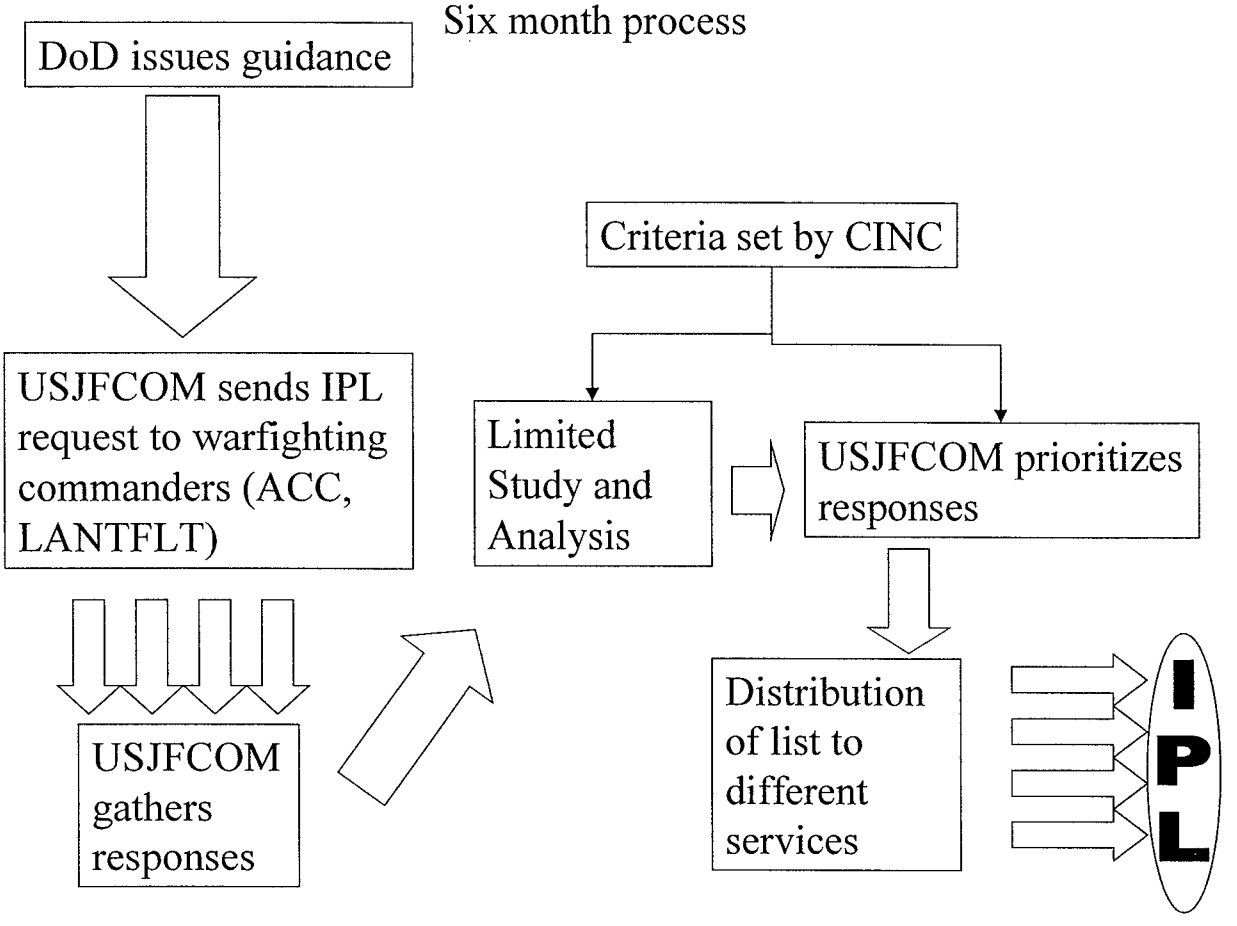

Figure 56. USJFCOM's Front-end Process

USJFCOM J-8, Requirements Interoperability and Strategy Directorate owns the process. A two-star officer, who reports directly to the USJFCOM Chief of Staff (COS), heads J-8. The COS reports to the Deputy CINC (DCINC), a three-star officer, who reports to the CINC, a four-star officer. The J-8 uses general survey techniques to gather user needs (i.e. the request sent to each component). When the user needs are collected, a process of combining redundant needs goes on. Simultaneously, very limited studies and analyses are done on some of the items that appear to be important (based upon the criteria of the CINC). These studies and analyses are not very thorough or numerous – the CINC has neither the time nor resources for many of these. USJFCOM has the smallest headquarters organizational staff of any of the other unified commands. Despite the organizational size, USJFCOM feels that extensive use of Knowledge Management techniques will offset any negative impacts of a smaller staff.

The last step to build the IPL is the prioritization process. This step requires the most time and is highly political in nature. It is wholly dependent upon the decision of the CINC. In general the IPL is not resource constrained. This is attributable to the fact that the warfighter is not as aware of the potential costs of a need or 'solution'. Additionally, it is likely that the 'needs' look more like 'solutions' to specific problems that exist.

Within USJFCOM there is a lot of discussion about how to even put the IPL together; usually it revolves around the criteria used during the building of the list. In order to understand the criteria used, a brief discussion is required. First, most Joint commanders are near or at the end of their careers. They are only involved with the joint command for 1 ½ to 3 years. Therefore, their focus is on immediate and short-term requirements (1 to 2 years out). The other issue is one where the IPL is used in the PPBS system. Most of the service POMs are already in their final stages by December, therefore, most of the IPL feedback is noted but not really acted upon. Second, the inherent time required by the process is such that by the time the requested item is even funded, the CINC may have already retired and another commander is there (with different priorities).

Additionally, the unconstrained nature of the IPL is reinforced by the actions of the PPBS. If every single item currently used or valued for use by the warfighter is not listed, even those items whose funding is seemingly secure or already exists runs the risk of not getting additional funding or even losing resources ("because it wasn't in their IPL"). These programs become targets for budget cutters during the never-ending PPBS cycles.

The last recourse for CINC priorities to get the necessary funds come through the JWCA process (the Joint Warfighter Capability Assessment). Here the CINCs can petition the Joint Chiefs of Staff (JCS) for funding or redirection of programs within the budget. Details are unavailable on the frequency the JWCA process being used in this fashion. If there is a need that absolutely must be met, the IPL requirement is usually met through emergency budget supplemental actions.

Organizational Issues

CINCs wishes, agenda, and desires drive the prioritization process of the joint commands. These invariably change from year to year and commander to commander. Reacting to these changes likely

introduces turbulence into the system. Furthermore, the responsiveness of the system, or lack thereof, is fueled by the long cycle times.

One of the strengths of the joint command's perspective is that it is integrated. Each branch of the service plays an integrated part in the execution of the commands activities. Therefore, interoperability among the services, for instance, receives the greatest priority. They are focused on the mission and are more concerned by the accomplishment of the mission than by inter-service rivalries (although they still exist).

Business Issues

USJFCOM has no resources of its own for product development. It relies upon the respective military branch's component commander to pursue product development. It does have a limited support budget for the activities of its headquarters staff. For instance, an air related issue would be funded by the Air Force and handled by the Air Force's Air Combat Command once notified of the need by USJFCOM. (Should this occur, this action would be an example of 'top-down direction' and the requirement would not likely be found in the service's MAP.) The military is organized such that component commanders are empowered to 'train and equip' while the joint commanders are to 'fight and win'. This is a legislated division (currently found in Title X statutes of the US Government).

USJFCOM would like to expand its role in Requirements Advocacy. In its role, the J-8 would like to receive and integrate all of the unified IPLs into one standalone document. Additionally, J-8 would like all requirements documents (regardless of their size and scope) to be reviewed and pass through their organization. However, this is not yet practical at this time considering the size of the staff in J-8 - but it is in their long-rang plan. The command also has indicated a desire to have a seat on the JROC, but the rationale for this desire is unknown.

Summary

Overall, USJFCOM has a defined front-end process, albeit an abbreviated one. Its role as the 'Chief Advocate for Requirements' is relatively new (about 1 year old). It uses a method (a survey – although it is one that will not be treated the same way in each service) to elicit user needs. Their method tries to screen ideas by collating them and organizing them in a fashion. Additionally, some analysis, although it is quite scarce in depth and rigor, is done.

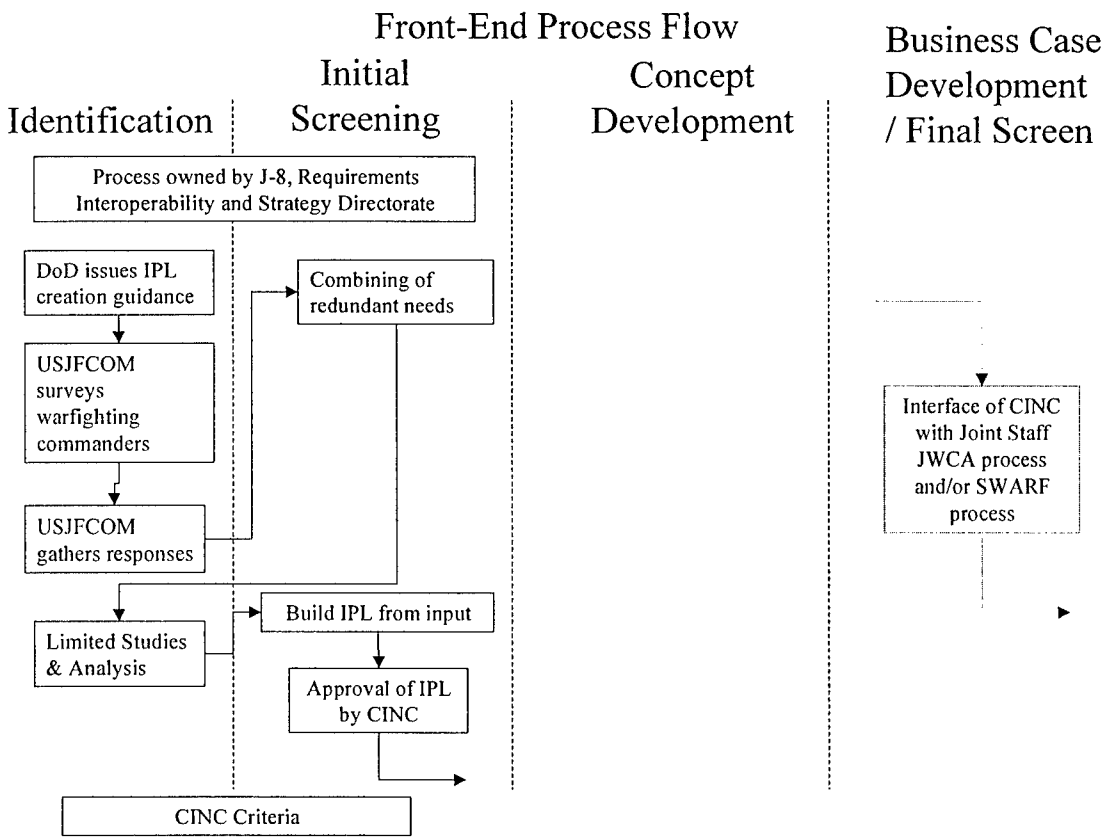

Figure 57. USJFCOM's Front-end in Terms of the Framework

The above diagram seems to indicate that this process somehow leads to a business case. This is not so. However, it does contain elements of the idealized framework, such as initial screening, analysis, as well as final approval that warrant the presentation of the process flow as shown above. However, in reality this process is the very front-end for many other processes in different branches of the military (if viewed as an input to the different service planning processes).

One clear weakness is in the area of analysis. The weakness is that the organization does not have enough resources to adequately do its job to analyze the alternatives that exist between the services for a mission task.

Nevertheless, a strength of the process is the IPL is an integrated look - not for just one service, but for the warfighter how to best accomplish the mission task. One area of concern might be the lack of the process being able to distinguish between true needs of tomorrow and outright solutions for today.

Many would argue that due to the short-term nature of these lists, this is a strength. Indeed, many of these needs can't go through the drawn out product development process of the military. The IPL may serve as finding the right balance between the immediate pressing tasks of today and preparing for the future long-term capability.

NORAD Front-end process

NORAD is the North American Aerospace Defense Command. It is a bi-national, joint-service command between the United States of America and Canada. This is a unique relationship, as their processes must correspond with those of two countries. It has control over its resources in a similar fashion to the US Air Force's MAJCOMs. Actual product development is spread between the two countries and their respective acquisition processes. It is also unique in that it may generate Mission Need Statements as a service does.

NORAD began with an agreement with Canada in 1958. This agreement has been renewed eight times and the latest renewal was in 1996. It currently has two missions: Aerospace Warning and Aerospace Control. NORAD begins its front-end process by conducting a Mission Area Analysis (MAA). The inputs for this are varied and include threats, policy, technology, budget, capability, strategy, and doctrine. As part of the MAA, NORAD will determine capability shortfalls, deficiencies or opportunities and state these in terms of a Mission Need.

The following diagram illustrates the high level process that exists for product development for NORAD. More detailed discussion about the elements of the process are found after the diagram.

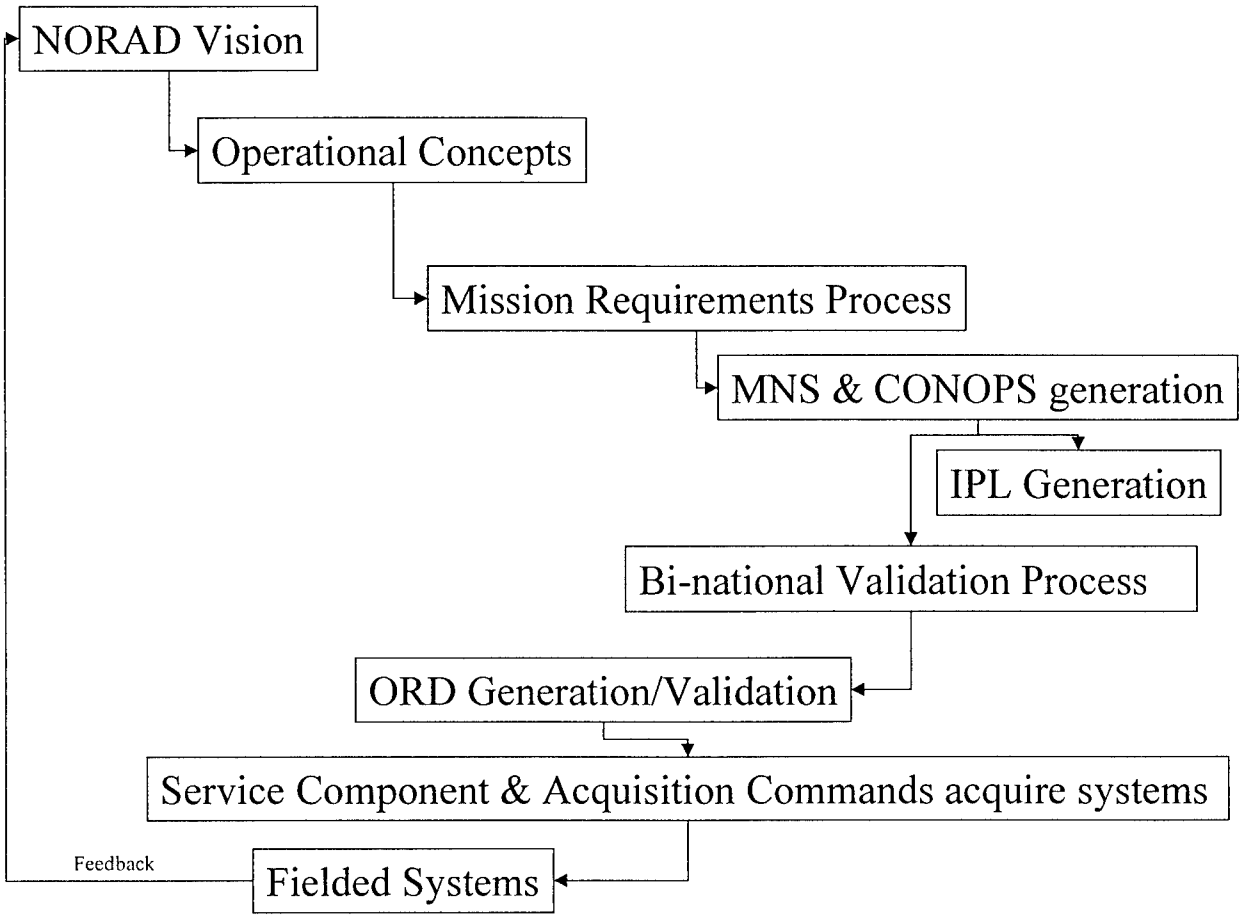

Figure 58. NORAD Implementation of Requirements

There are three basic activities of NORAD in terms of requirements. The first is preparing a Mission Area Analysis (MAA). The second is preparing an Integrated Priority List (IPL). The third is the preparation of any Mission Need Statements (MNS).

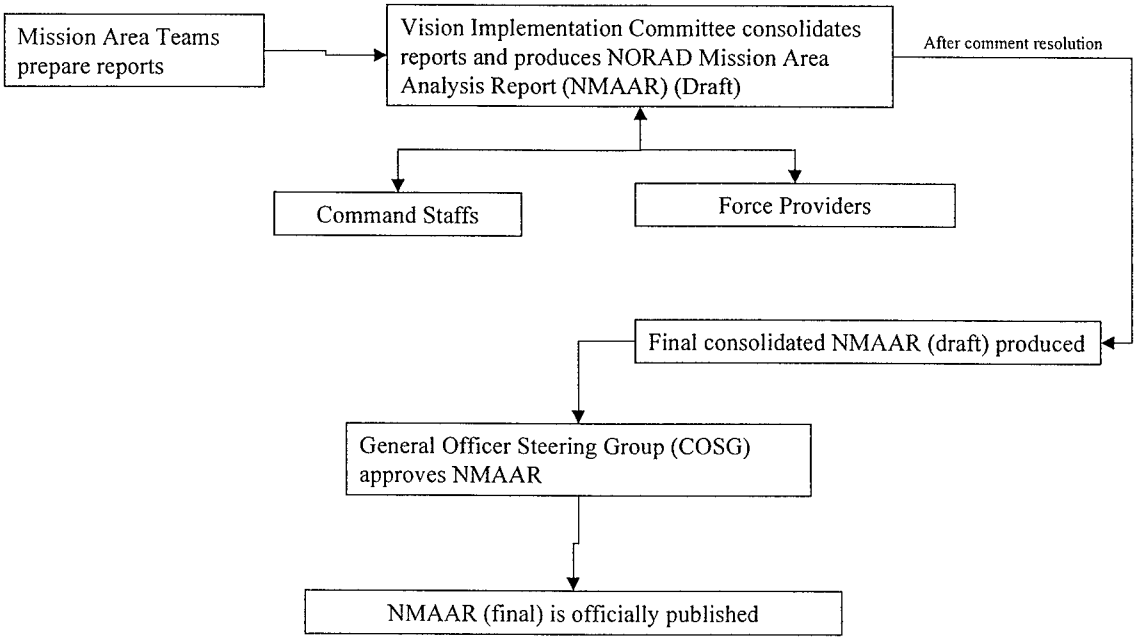

Figure 59. Flow of Mission Area Analysis of NORAD

A cross-functional team that reviews all of the different inputs and conducts analysis on those inputs conducts Mission Area Analysis. There are five teams that conduct a Mission Area Analysis. The process lasts approximately one month and their output is a report for each team that contains their findings. These individual reports are reviewed and consolidated by a Vision Implementation Committee. There are 9 members on the committee, plus a secretary and chairman. The Director of Plans, a one-star officer, chairs the committee. Other members represent planning, requirements, Manpower & Personnel, Intelligence, Operations, Logistics, Command & Control, and Analysis. These members are all Colonels or their equivalent. The committee produces a draft report. Once the draft report is put together, it is sent for review to the different internal staffs within NORAD as well as the Force Providers (US Space Command and the Canadian Space Equivalent). Feedback is

obtained and reviewed by the Vision Implementation Committee. This process requires approximately 3 months to complete.

Once all of the different comments are consolidated and resolved, the updated draft report is sent to the General Officer Steering Group (GOSG) for approval. Approval actions require approximately one month to complete. Once this is approved, the report is finalized, published, and distributed. The report is NORAD's baseline document for identifying deficiencies. It is called the NORAD Mission Area Analysis Report (NMAAR). This document is the foundation for the Integrated Priority List (IPL) development. It is also the source for new Mission Need Statements, as well as Non-MNS corrective actions.

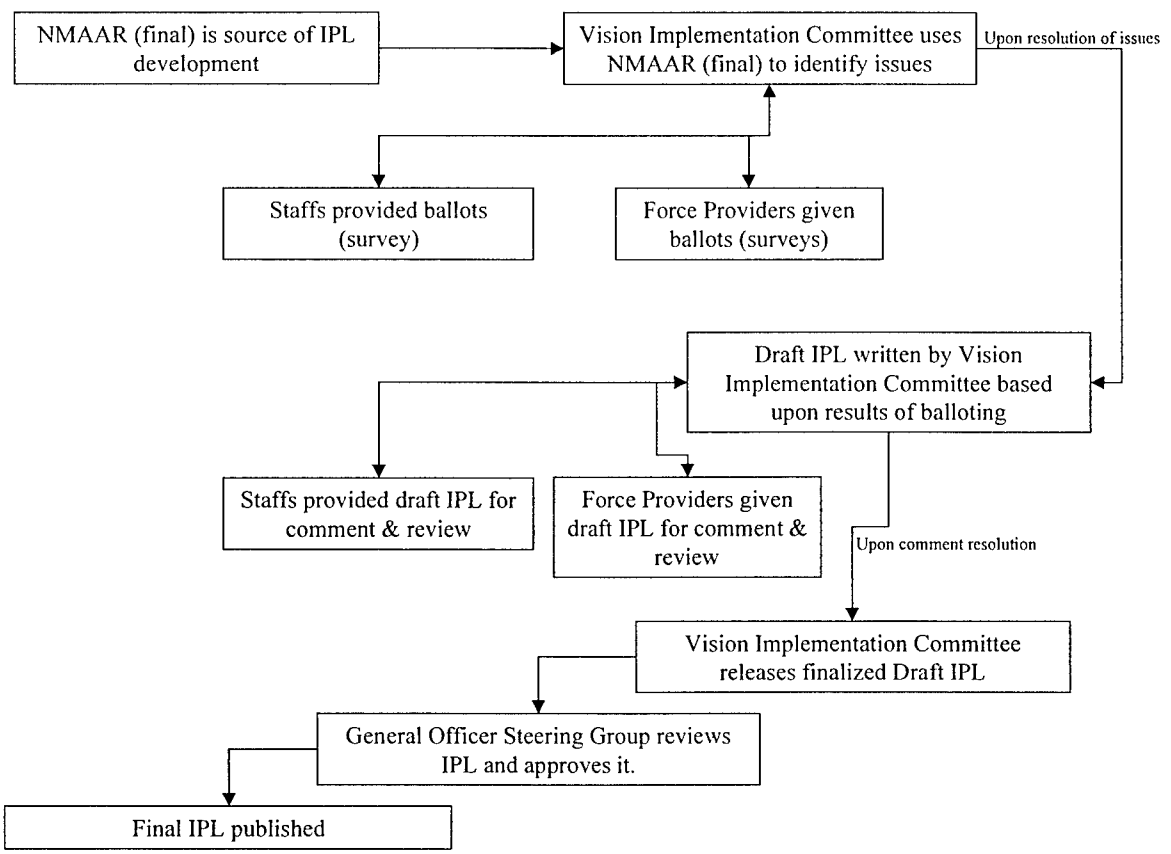

Figure 60. NORAD process for Integrated Priority List (IPL) Development

The Vision Implementation Committee does the IPL development. The committee collates the different issues present in the NMAAR and prepares a ballot of those issues. This ballot is sent to the staffs and also the force providers to be returned to the committee with a subjective ranking on which issues are more important than other ones are. This process requires approximately two months.

The Committee takes these inputs and drafts a new document called the Integrated Priority List Draft. The draft is again sent to the staffs and also to the Force providers for comments and review. The comments and remarks are addressed and/or resolved before moving to the next step of the process. This step requires approximately two months.

For the final approval of the IPL, the vision implementation committee sends the updated draft IPL to the General Officer Steering Group. This Group deliberates over the particulars of the document and gives their approval in one to three months time, depending on the content of the IPL. When approved, the IPL goes to US Space Command (as well as the component commanders and their counterparts on the Canadian side) for their use.

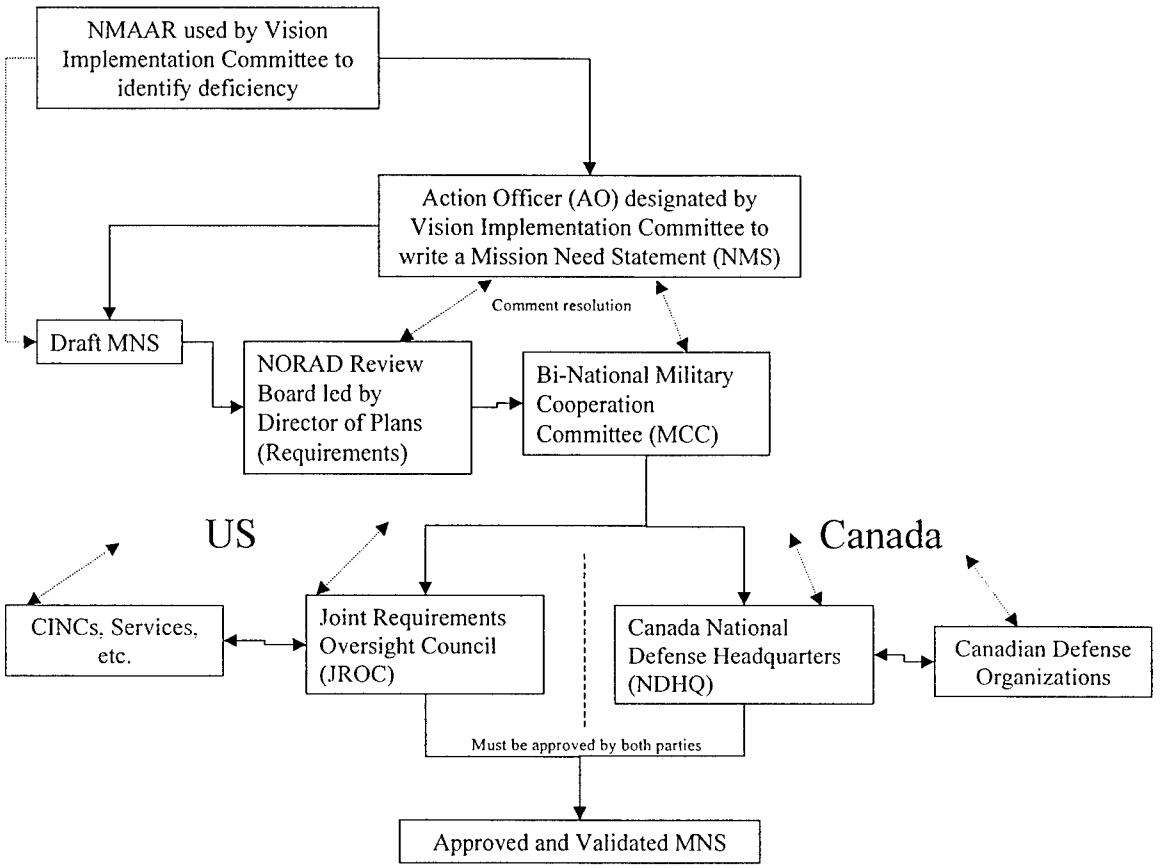

Figure 61. NORAD Mission Need Statement Process

When NORAD determines to write a Mission Need Statement, the Vision Implementation Committee designates a particular office to be responsible to develop the Mission Need Statement. The first step is the assignment of an Action Officer who is responsible for the Mission Need Statement. Each of the additional steps in the process (which correspond roughly with organizations) has the ability to make comments and stop the validation and approval of the MNS until they are resolved. The next step in the process is to write a draft MNS that is then staffed internally to NORAD for comments and review. Once those comments have been consolidated and resolved, the draft MNS is sent before a NORAD review board. Once approved, the MNS is sent to the Military Cooperation Committee between the US and Canada. When there are no issues preventing it from further development, the MNS is sent into the different approval processes for the US Military and the Canadian Military. On the US side, the Joint Requirements Oversight Committee (JROC) and joint

staff distributes the MNS to each of the services and the Commander in Chiefs (CINCs). (It is highly likely that these players have already seen advance copies and/or drafts during this entire process). The Canadian National Defense HQ staffs, validates, and approves the document according to their processes. Once both bi-national partners have validated the MNS, it is considered approved. There is no official timeline for this process. If the need in question is only related to US based needs, the MNS will go from the NORAD review board directly to the JROC and proceed through the system as indicated earlier.

Further development of a MNS into an ORD and eventually into materiel solutions go through the different component services and commands. For instance, the AF Space Command will conduct an AoA along with the help of the Space & Missile Center (acquisition) and together will draft the ORD. The ORD will be staffed through the system as described for the Air Force. The same would also be true for the other services and their processes.

Organizational Issues

The Organization of NORAD is unique in that it is not only joint, but also a bi-national command. The dual nationalities lead to some different organizational arrangements. As part of the NORAD agreement, an American Officer is always the CINC of NORAD. A Canadian is always the Vice CINC. Since NORAD plays such an important part for the National Security of the United States, the military officer in charge of NORAD, is also the Commander of US Space Command. When an Air Force officer is the NORAD and US Space Command CINC, that officer is also the Commander of the Air Force Space Command. This arrangement is designed to prevent organizational barriers from being formed among the different commands. Also, the same individual fills most of the positions in each of the directorates in NORAD and the US Space Command. For instance, this means the Director of Plans is the same person for both NORAD and the US Space Command.

Business Issues

NORAD only has a budget and resources that directly relate to its Headquarters Building and the Cheyenne Mountain Operations Center. The respective country's militaries and their respective component services and commands physically own all other assets. Therefore, the needs of NORAD can only be met when another organization (a service, service component, etc.) decides to acquire the capability advocated by the Integrated Priority List (IPL) and/or Mission Need Statement (MNS).

Summary

The process in use has some comparisons with the idealized framework. It begins with an activity that gathers inputs to the process. Cross-functional teams organize them and put them into context during this gathering.

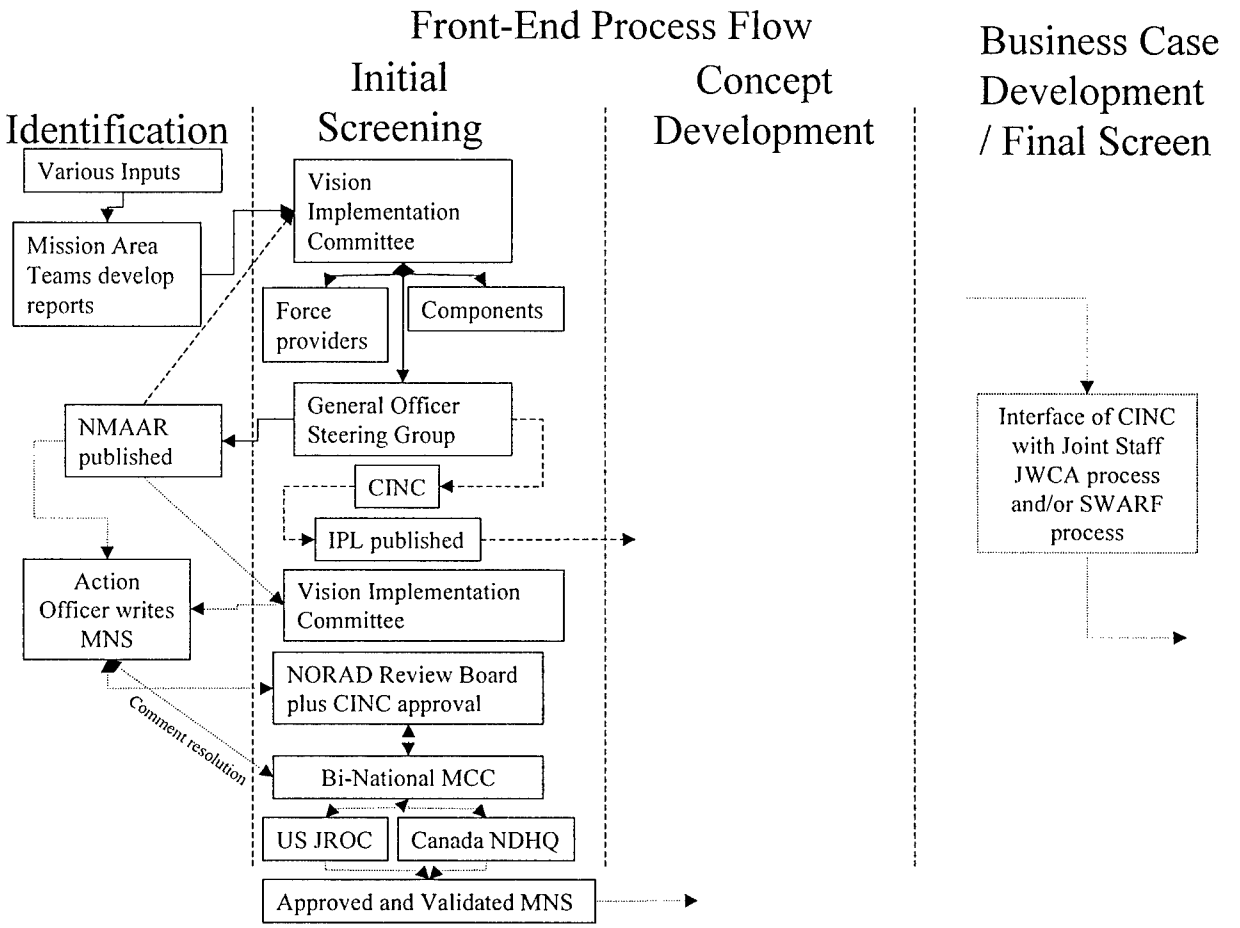

Figure 62. NORAD Front-end Process in Terms of the Framework

A single committee does most of the consolidation work and preparation of the general requirements for the organization. This is in essence a screening process. Upon completion of this first screen, a second committee of more senior individuals reviews the material. This committee consists of the second screen. As the needs identified are selected to be developed into Mission Need Statements, these same committees review these statements. The same occurs during the development of the IPL, although there is a more formal and structured way for participation in the development of this list.

Finally, the last screen is an implicit one that occurs as the MNS seeks the sponsorship of another organization to conduct further analysis on the need and develop an operational requirements document. The screening occurs as a MNS is picked up for development or not.

US Space Command

This command is a unified command of all four US military services. It is responsible for worldwide United States Space Assets and their operation. In addition, NORAD is one of its chief customers.

It has a formal front-end process. The following diagram indicates the overall process flow that exists and will be followed by more detailed information about the process.

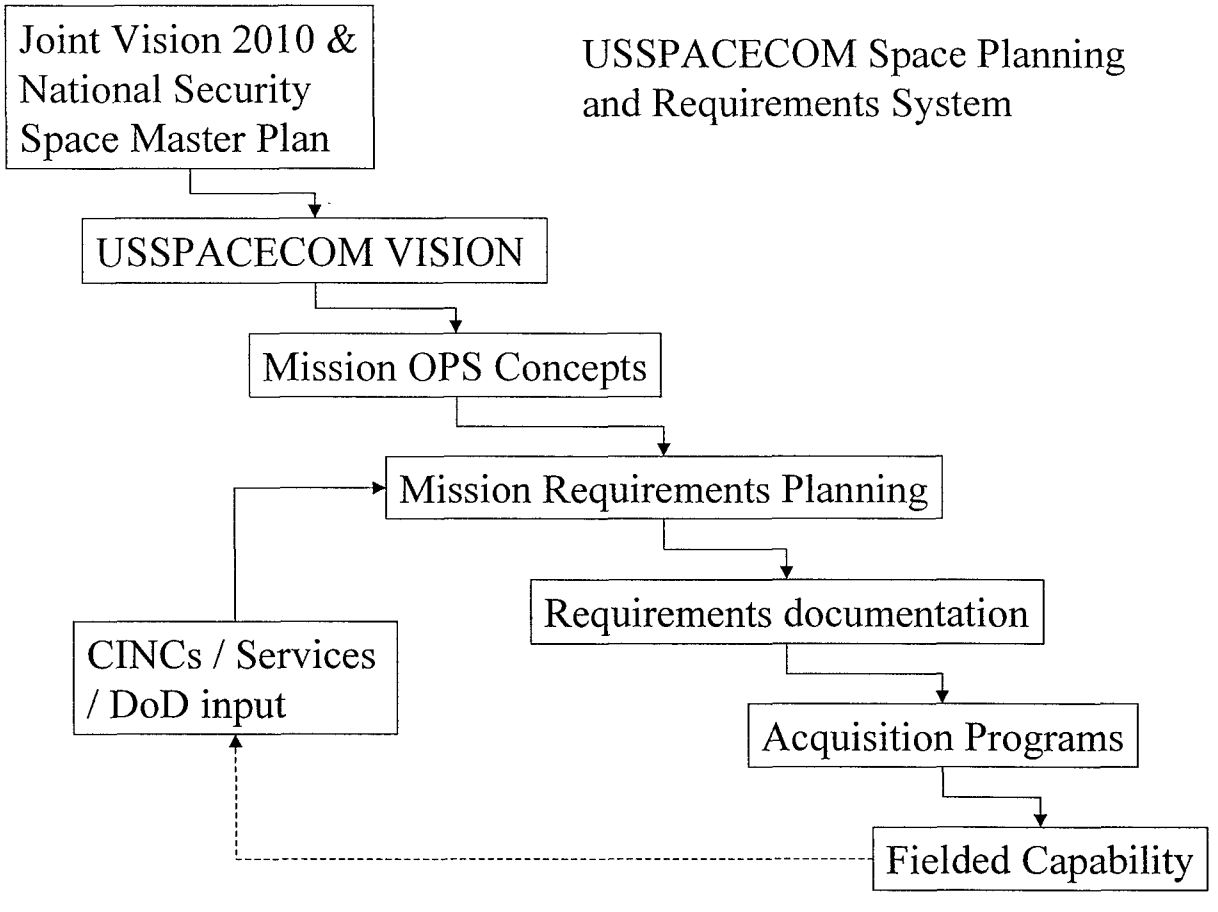

Figure 63. USSPACECOM Planning and Requirements System

The system process internal to USSPACECOM produces several items that facilitate getting the final product or capability to the warfighter. Among these are the Vision for the Command, the Long Range Plan (which contains many of the Operational Concepts for the command), a Long-range Action Plan, Master Plans, Roadmaps, Integrated Priority List (IPL), Program Objective Memorandum (POM) inputs, as well as Mission Need Statements, and Operational Requirement Documents. All of these are produced as a part of the process.

The overall process is planned, controlled and executed by one organization, J-5, the Directorate of Planning. The J-5 is a one-star position at USSPACECOM. The process is continually active. It is not strictly serial in its operations. The vision for the command is updated yearly, and the Long Range Plan is updated twice a year. The Roadmaps are updated continuously to maintain their six-year look.

The following diagram outlines the organization outlook of the process. Each product of the process goes through the process flow outlined. Detailed explanation will follow in subsequent paragraphs.

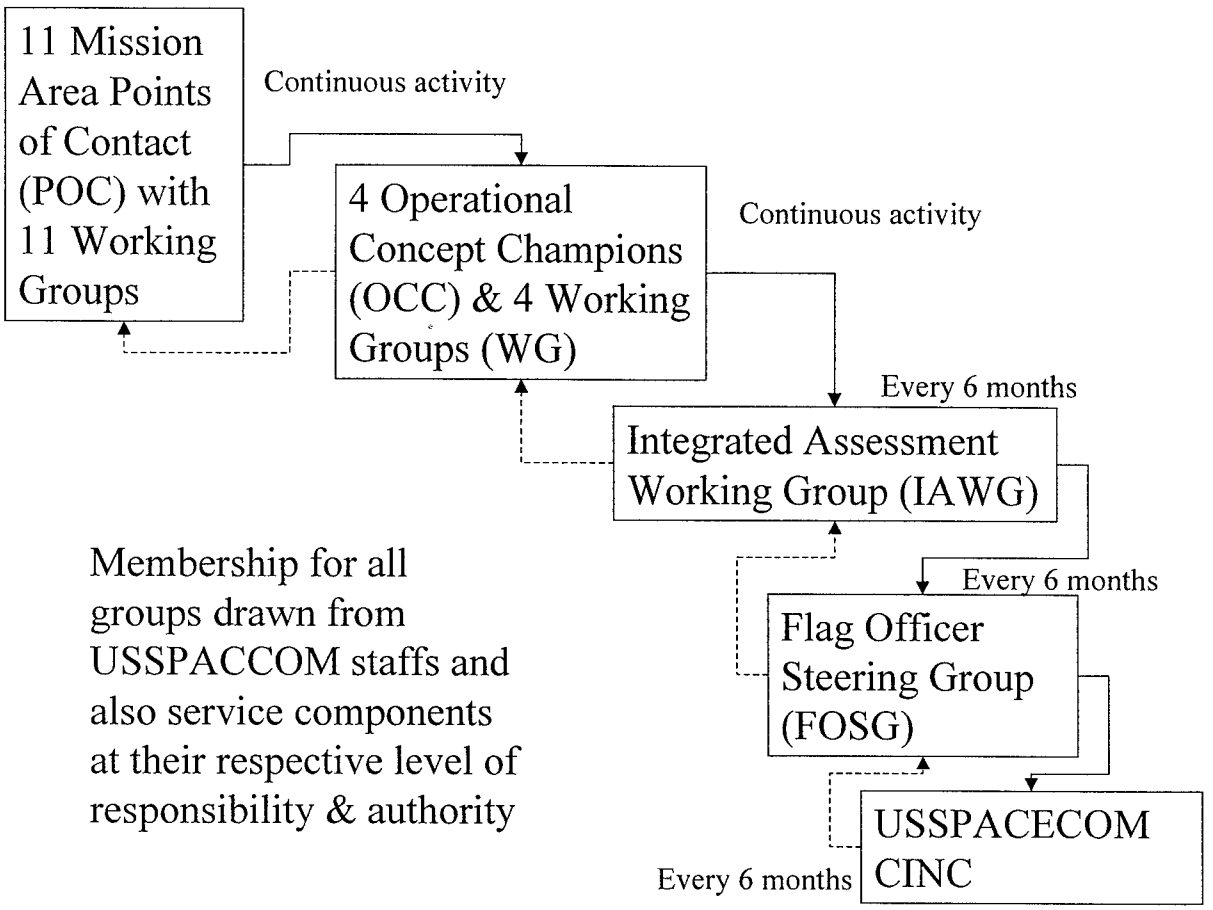

Figure 64. USSPACECOM Organizational Process Flow

USSPACECOM has identified 11 Mission Areas that it is responsible for. These are things like Space Control, Navigation, Warning and Assessment, Meteorological and Oceanographic, Communications, Reconnaissance and Surveillance, Force Application, Spacelift, Earth Resource Monitoring, Command and Control, and Satellite Operations. The 11 Mission Area Teams (MATs) are used to provide in-depth support and expertise to the Mission Area Point of Contact (POC). The POC is expected to be the functional expert in the particular mission area and provide detailed information on capabilities, CONOPs and organizations as well as systems, technologies and partnerships required to achieve specified objectives of the Long Range Plan operational concepts. The Working Group (WG) is also used for detailed information to build the vision, and long range plan. After it is built, the group constantly probes the understanding of the group members to develop other mission needs, further develop deficiencies, and missing capability.

The Operational Concept Champions (OCC) are responsible for actually writing the Long Rang Plan. Additionally, they write the Long Range Action Plan semi-annually outlining what steps need to be taken to implement the Long Range Plan (LRP) as much as possible within the next six years. The OCCs update the vision and manage the updates of the LRP as required, and ensure that appropriate products are produced - like the IPL, Requirements Documents, etc. (The service components are to be the primary data provider for development of the Six-Year Roadmaps and system and technology inputs.) The OCCs chair four working groups. These working groups are made up of all of the Mission Areas POCs and a matrixed cross-representation of personnel from the directorate, component, and other agencies.

Shortfalls are identified by the OCCs as they continuously update the six-year roadmaps and identify proposed changes/updates to the LRP. This also includes identifying other shortfalls against identified requirements from other sources such as other Unified CINCs. All of these shortfalls are then prioritized and consolidated with the help of the common IT database and decision assistance tool known as the Automated Database and Expert Planning Tool (ADEPT). The information contained in the tool forms the basis for IPL development.

The Integrated Assessment Working Group (IAWG) actually develops the draft IPL. Additionally, the IAWG integrates and provides guidance to the OCC Working Groups and reviews all of the products of the Planning and Requirements System. The members of the IAWG are all of the OCC Chairs, component representatives, and other designated personnel. Comments are collected and resolved. Then it is sent before the Flag Officer Steering Group (FOSG). The FOSG provides top-level guidance to the overall planning and requirements process, reviews issues and recommendations and provides guidance on the final LRP and IPL. The members of this group are all of the USSPACECOM Directors (they can be of differing rank (as low as Colonel and as high as 2-star general) depending upon importance to the command) and the component commanders. The Deputy commander of USSPACECOM chairs the FOSG. Comments are collected and resolved. The CINC of USSPACECOM then approves the document, either the LRP or IPL.

As far as requirements document development is concerned, the Mission Area POCs are responsible for identifying the Requirements Documents needed to address the identified shortfalls. They will also recommend either USSPACECOM or one of the components to develop the document. They will

draft recommended completion timelines that address the shortfall(s) of their mission element. A MNS that USSPACECOM decides to draft will follow the exact same process followed by the IPL and LRP development except that the IAWG members and FOSG members coordinate individually (no meetings are called) before the document is signed by the CINC. Then the MNS enters the Joint Requirements Process controlled by the Joint Requirements Oversight Council (JROC) for further action. USSPACECOM is able to draft a MNS but not able to pursue a requirement further (conduct an Analysis of Alternatives (AoA) or build an Operational Requirement Document (ORD)). It relies upon one of the service components to accept the deficiency, implement a solution or system to address the deficiency, as well as pay for program to correct the deficiency.

The Director of Plans, J-5, is also charged to review all POM documents, Budget Estimate Submissions (BES) and other PPBS documents to ensure consistency with the requirements outlined by USSPACECOM to include the PPBS documents of the components, particularly to ensure the components are supporting the IPL.

Organizational Issues

The organization is setup such that one single Directorate is responsible for the entire front-end to include advocating proper resource allocation in their components' PPBS process. The size of this organization doing all of this work is rather small. Since this organization is also functioning as the NORAD J-5, it does conduct the PPBS functions for NORAD's relatively small PPBS inputs.

The existence of four screening functions is remarkable in terms of the idealized framework. The product development space that the USSPACECOM process operates in is roughly that of the first two stages. Additionally, it is evident that many of the organizational structures overlap those of the component commands that attempt to do the same things.

Another interesting organizational fact is that when the Air Force is commanding USSPACECOM, it is also commanding the Air Force Space Command. Not surprisingly, the AF Space Command has many processes that are similar in nature to those found in USSPACECOM. However, another interesting feature is that there are times when the USSPACECOM CINC has to direct the AFSPACECOM CINC to do something and they simply agree to disagree. "The letter is signed twice by one person wearing two hats reaching differing conclusions."

Business Issues

SPACECOM has an integrated, sophisticated information technology tool. This tool is called the Automated Database and Expert Planning Tool (ADEPT). It is used to automate the Long Range Plan. This same tool contains an advanced decision making assistant tool that is used for decisions relating to prioritizing deficiencies and capability shortfalls. This tool is the foundation for the development of the IPL and all other products of the Space Planning and Requirements Process.

Summary

The USSPACECOM process is well thought out in terms of explicitly linking planning with requirements. Additionally, the use of the ADEPT tool is by far the most sophisticated tool in use by the Air Force today. The use of the tool allows four screening processes to occur twice a year or even more frequently as occasion requires. Other services or unified commands with similar screening structures are not as agile in their process flow capability.

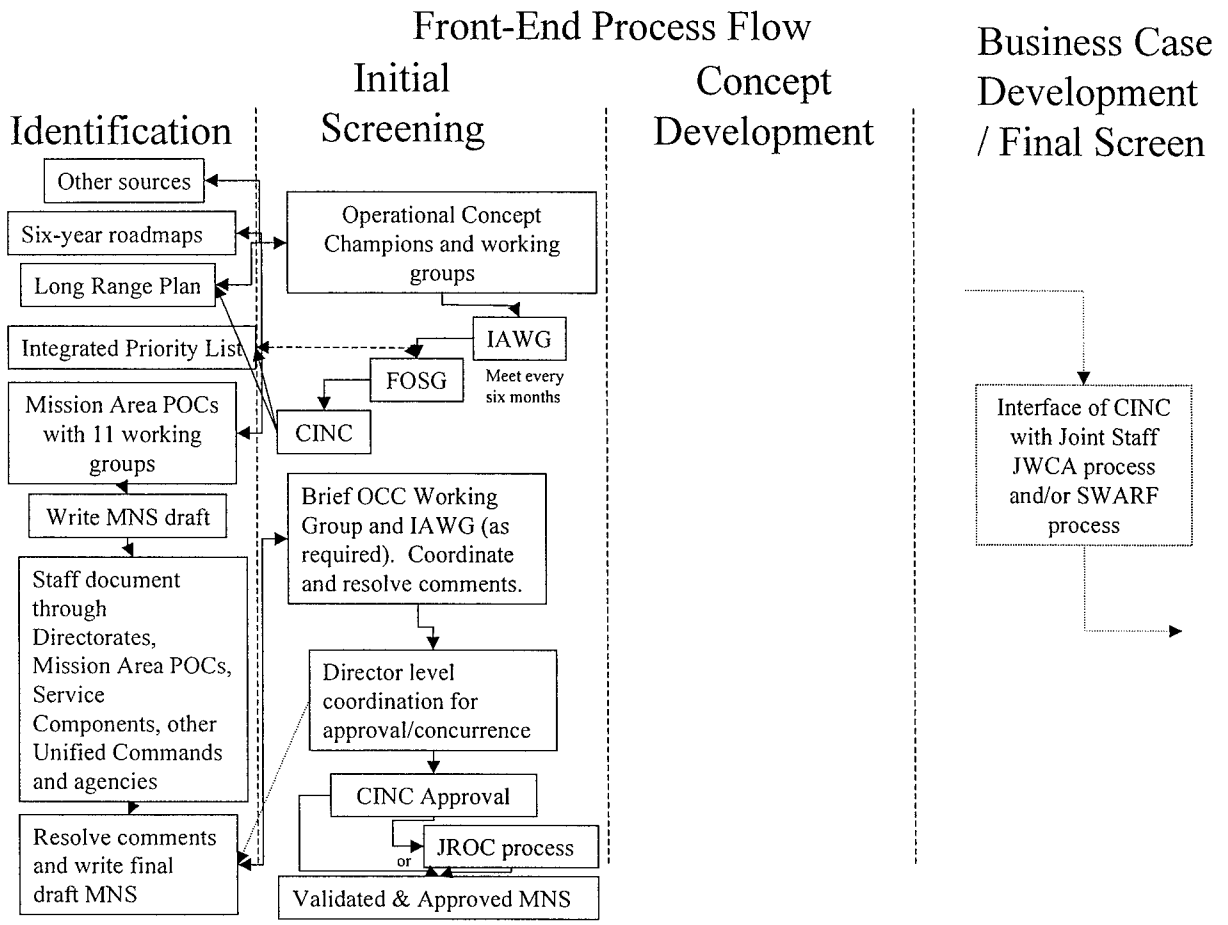

Figure 65. USSPACECOM Front-end in Terms of the Framework

This process is also mature because it allows for and even expects multiple sources of needs and requirements. However, it seems unable to guarantee the approved needs will get the funding it requires for further development. This is strictly the result of the process being split between the unified commands and the service components. This split allows a service component to further its own unique goals and objectives that are separate from those of the unified command they support. Although the joint leadership should dissuade this from happening, it does not according to interviewed sources.

CHAPTER 7 - OVERALL DATA ANALYSIS

Each of the case studies was scored using the Maturity Matrix. The relationships to the idealized framework have already been made in the case study writings. This chapter indicates the relative performance of each organization in relation to the Process Maturity Matrix contained in the framework.

Discussion

As the framework asserts that Organizational and Business Enablers are required for an advanced front-end, and that this advanced front-end demonstrates characteristics that are desirable; it is hypothesized that the enablers will be positively correlated with each stage of the framework as well as with the overall process.

The coded data from the maturity matrix was evaluated according to its correlation coefficient and its confidence factor. Correlation analysis measures the strength of relationship between two variables. A positive correlation indicates that large values of one variable are associated with large values of the other variable. A negative correlation indicates that large values of one variable are associated with small values of the other variable. If a positive correlation exists, it does not mean that one variable causes the other variable. Although there may be a causal link between the two variables, the measure of correlation does not prove a link exists. The confidence factor indicates the level of confidence (the probability) in the outcomes of the data analysis (or that the data is in fact correlated).

One correlation test statistic is the Pearson product moment correlation coefficient, or r. It is a dimensionless index that ranges from -1.0 to 1.0 and reflects the extent of a linear relationship between two variables. R-squared is the proportion of the variance in y attributable to the variance in x.

The r measures assume a normal shaped distribution of the data. Due to the small sample size, however, normality of this data is difficult to determine. One method is to look at a histogram of the data and see how it might compare to a normal shaped curve. For example, the data for the Identification of Requirements Phase can be represented as a histogram in this fashion. All of the variables were examined in this manner.

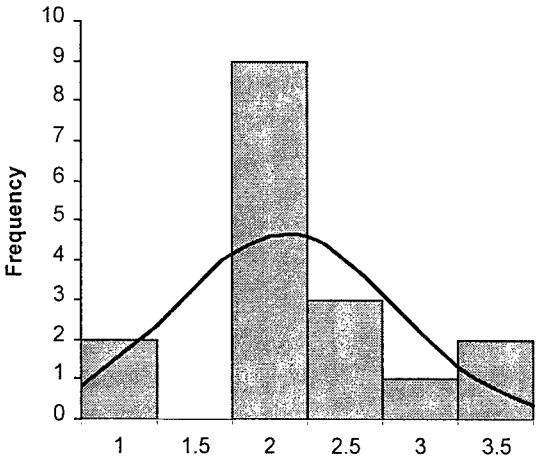

Figure 66. Identification of Requirements Phase Data Histogram

While the majority of the data lies at the center of the curve, it has several outliers (pieces of data that don't seem to belong) that question the proper relationship as a normal distribution. Another representation of this information is to plot the relationship between the values of the data and the normal quartile. A normal data set will approximate a straight line. The following graph, using the Concept Phase data, is shown below.

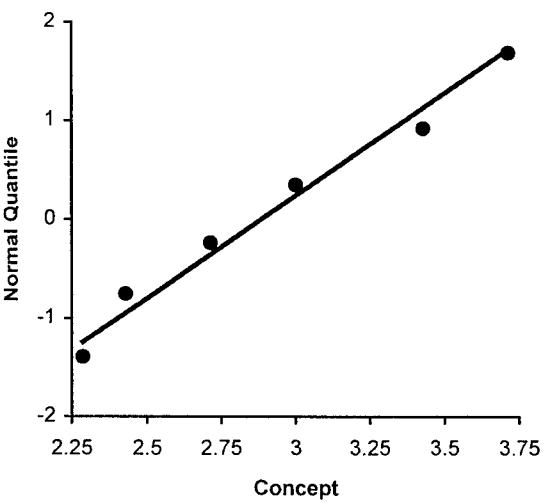

Figure 67. Concept Phase Outcomes vs. a Normalized Line

As can be seen, the data is spread across the normal line plot, and if a line were drawn connecting the data points, that line would approximate a straight line. These tests were done for every variable and each of them displayed similar results to Figures 66 and 67. Therefore, using this analysis, a normal distribution of the data is assumed.

Findings

The data scored in the maturity matrix was separated into the different phases and enablers. The scores for each of the elements in each phase and enabler were summed then scaled to a four-point scale. The following charts graphically indicate the outcomes of the different phases of the maturity matrix. They are ordered from lowest score to highest score among the different organizations.

The Identification of Requirements Phase Average Maturity Score for each organization is displayed in Figure 68.

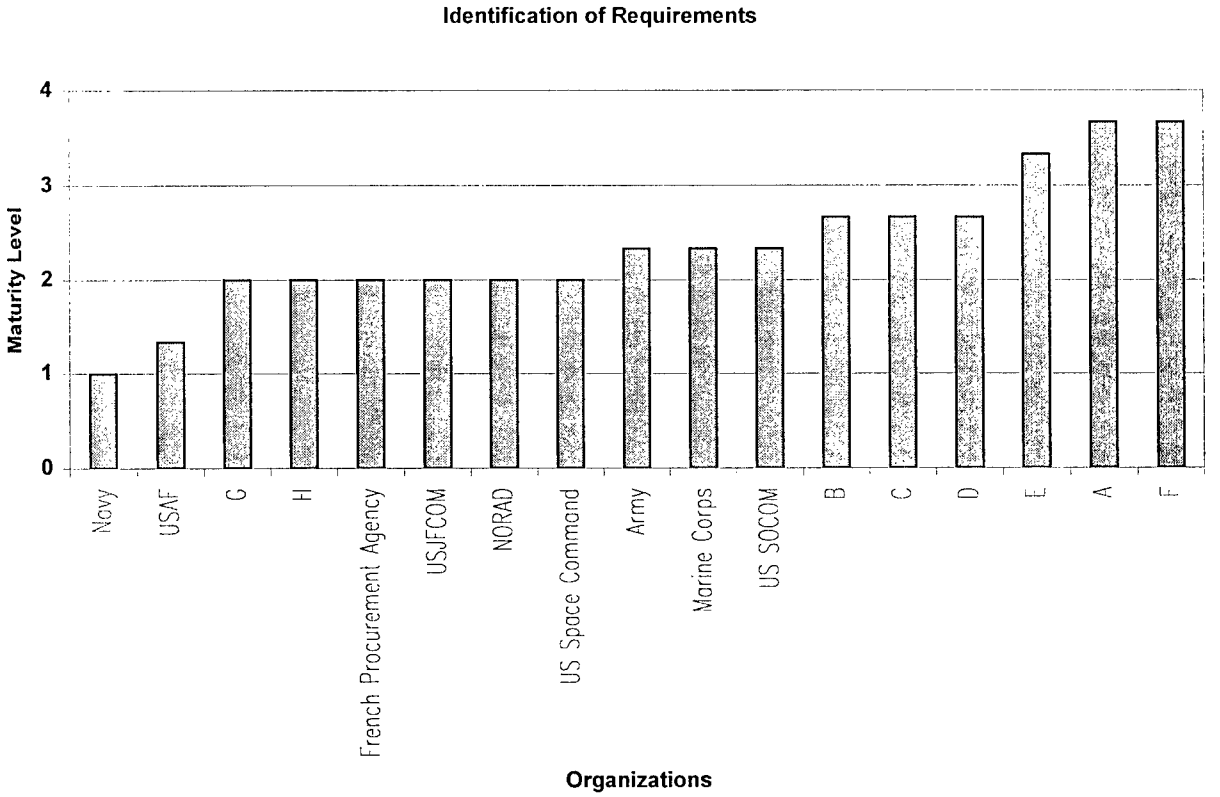

Figure 68. Identification of Requirements Phase Outcomes

Figure 68 shows that most commercial companies have much more mature requirements identification processes, while military organizations show more room for process improvement. The Navy and US Air Force have the least mature processes in this area. Part of this reflects the organizational structure in place that is used to identify requirements. The Planning processes for both of these services are relatively disconnected from the actual process used to develop the documentation for the later phases of the front-end process.

Figure 69 displays the overall process maturity for the Initial Screening phase of the front-end.

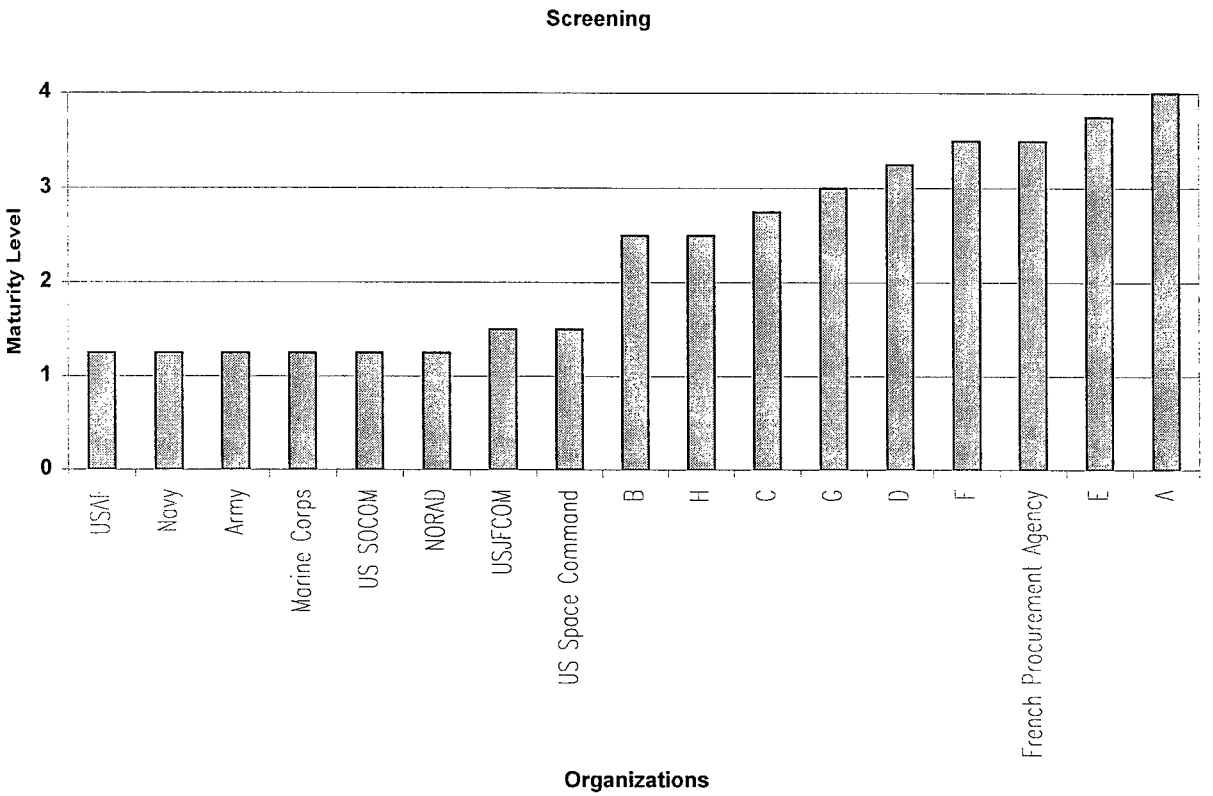

Figure 69. Initial Screening Phase Outcomes

Again, the outcome of this phase reflects the overall division of process maturity between the commercial industry and the military. Among the most decisive factors in this area are the control and distribution of resources for further development. Most military organizations are completely dependent upon other organizations within those military services or commands to release funding as

well as obtain permission to proceed into further concept development of the need or idea. None of the commercial companies or the French Acquisition System have these barriers in place. Consequently, their processes reflect much more maturity.

Additionally, the contributing factors to this phase represent linkages with other processes such as technology development and other projects currently being developed (i.e. portfolio management). Understanding the consequences of proper risk management in the early stages of development also plays a key role. Again, in all of these areas, commercial industry reflects more process maturity than do the military organizations.

The Figure 70 displays the concept development phase.

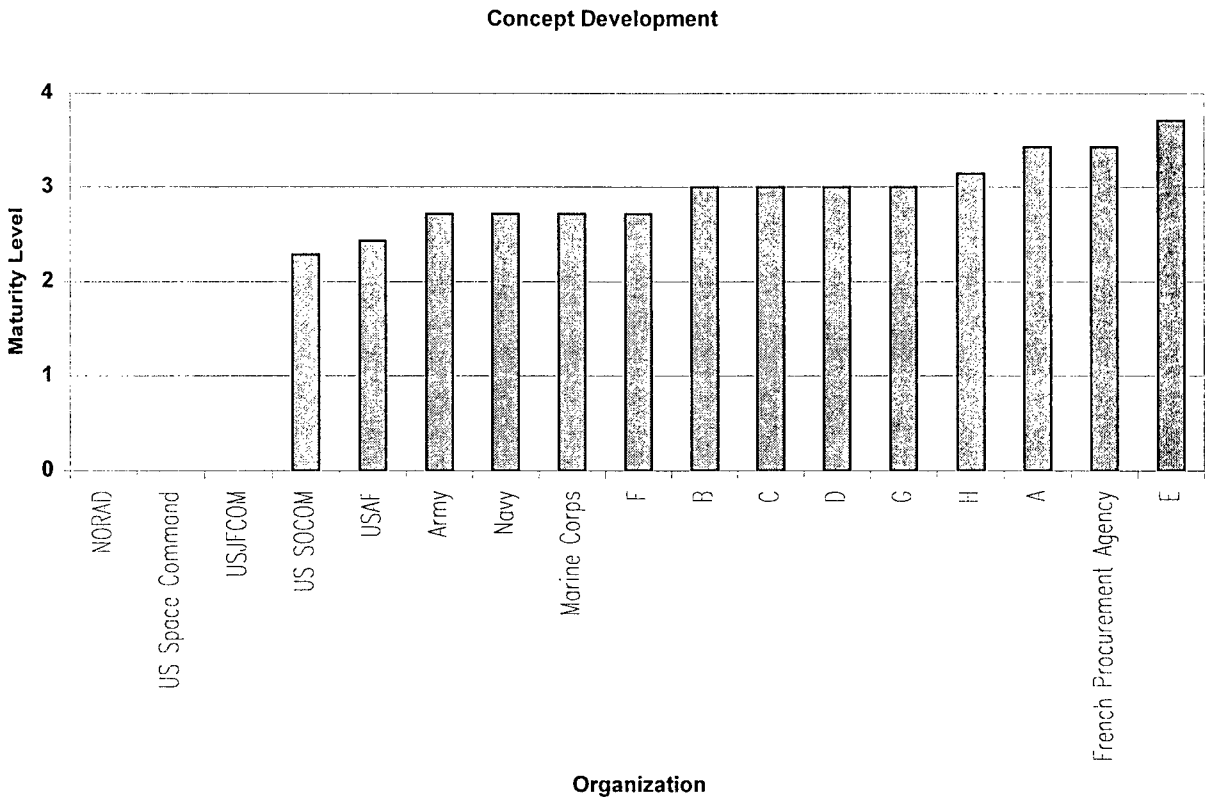

Figure 70. Concept Development Phase Outcomes

Concept development is not conducted by three of the unified commands, as reflected above. Nevertheless, the military and commercial industry have reasonably developed concept development processes, with the commercial industry usually having more mature processes than the US Military. One of the phase elements that contributed to the lower process maturity ranking for the military was the kind of requirements prioritization that is done. More mature processes identify and prioritize requirements not only into 'must have' and 'nice to have' categories, but also within those categories. Furthermore, the military system is not designed to accommodate the presence of requirements that 'delight' the customer and are usually not communicated by the originator of the need or requirement.

The Business Case Development Phase in displayed in Figure 71.

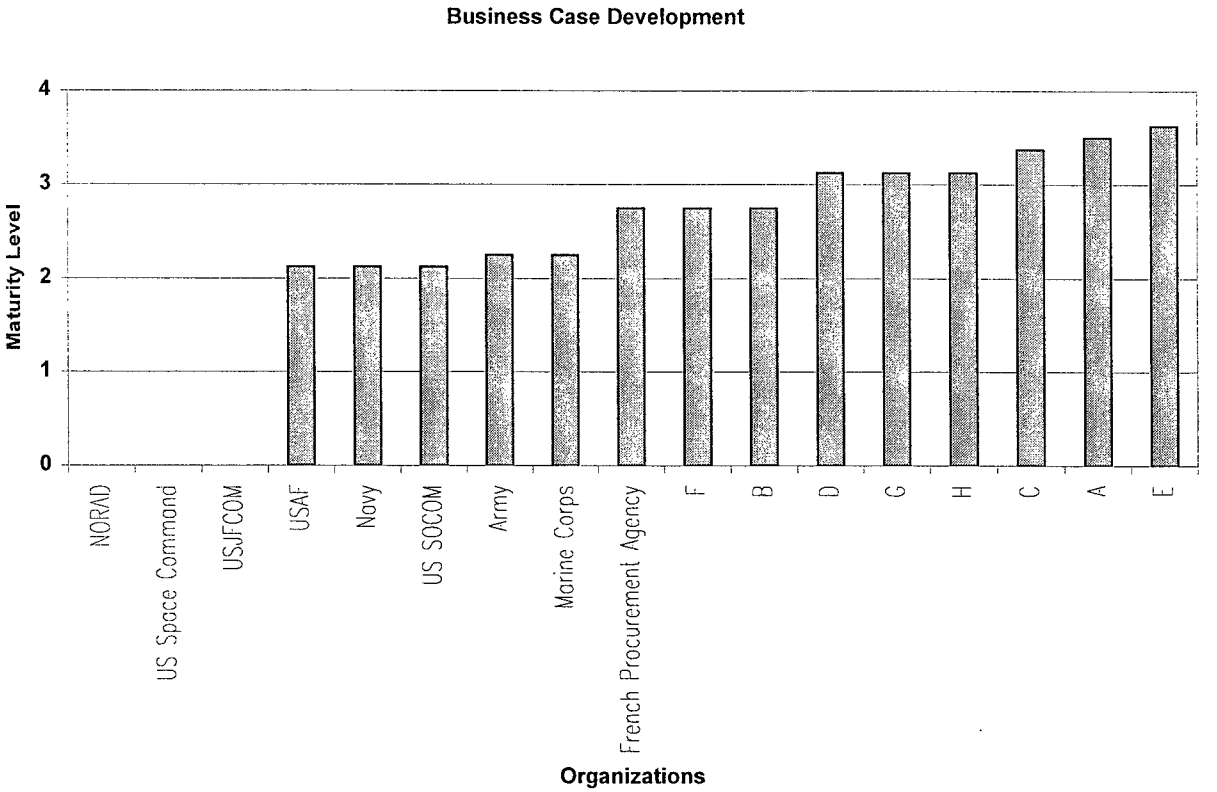

Figure 71. Business Case Development Phase Outcomes

Again, in this phase three of the Unified Commands do not participate and are not reflected in this graph. Also, the military business case development processes' level of maturity is usually less than

that of most commercial companies. Company F's level of maturity is no worse than the level of maturity of any of the military processes. This may reflect Company F's close ties to the overall front-end process within the military. Company F's business cases are dependent upon the military's determination to pursue development of a need or requirement.

The items that differentiate the outcomes in the business case development process phase are attributable to the allocation and dispersion of resources to proceed into the regular new product development process and their linkages to other development projects as well as linkages to necessary or required technology development processes. The military processes have mechanisms in place for these things to occur, such as using a Milestone Decision Authority to ensure the linkages are in place, however, the military's processes do not reflect the maturity of those mechanisms in place for commercial companies.

The performance of the overall front-end process is reflected in Figure 72.

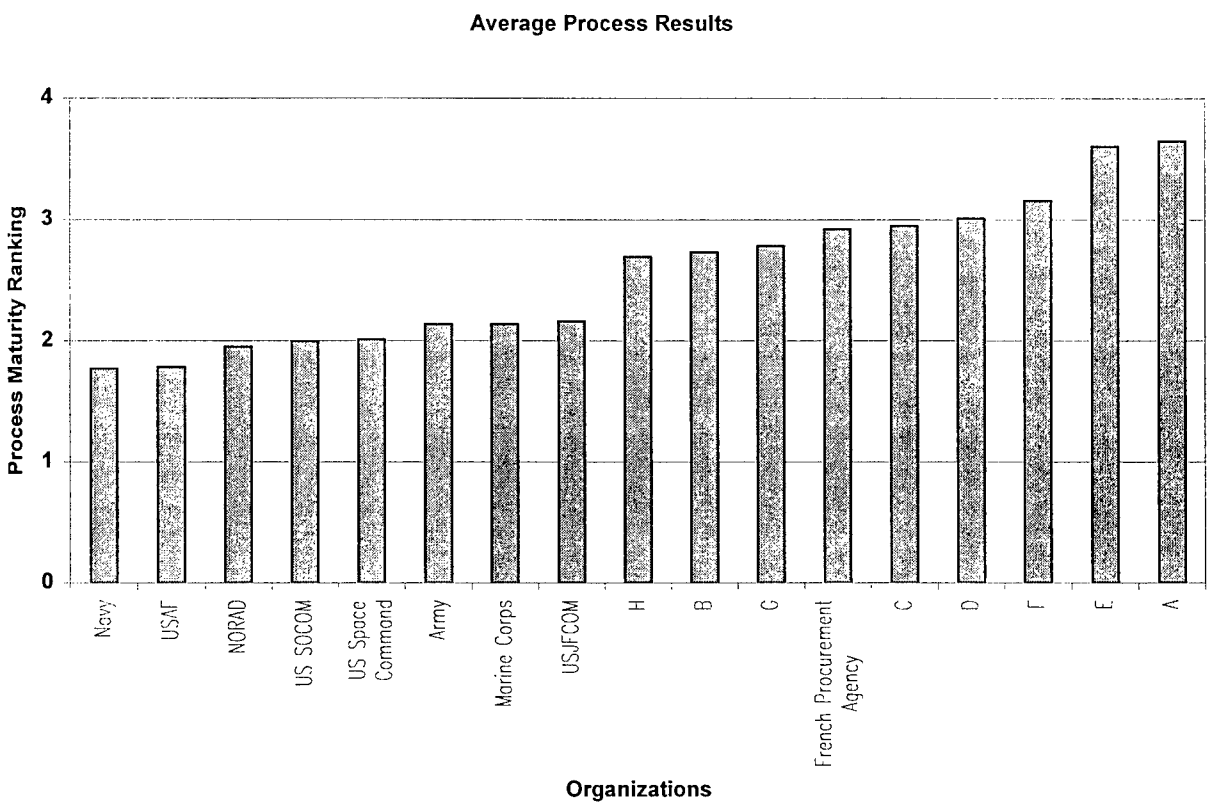

Figure 72. Overall Process Outcomes

This graph represents the overall process maturity of all four phases of the front-end process. Typically, commercial organizations outperform the military in terms of process maturity. The Army, the Marine Corps, and USJFCOM seem to have the most mature front-end processes of the US Military organizations. These outcomes should not be surprising after reviewing the individual outcomes of each of the front-end process phases[48]. The Army and Marine Corps do not separate Mission Area Analysis or Mission Needs Analysis from the Requirements Process. They are viewed as an integral part of the process (whereas the Navy and Air Force view them separately). Additionally, both services use a team to develop their needs and requirements. Finally, both services use a formal process to prioritize their needs and requirements prior to entering the PPBS process (the Warfighting Lens Analysis (WFLA) process). USJFCOM benefits from the overall influence of the Army and Marine Corps; in addition, the Air Force component (Air Combat Command) uses a similar formal prioritization scheme (the Modernization Investment Plan (MIP) for its needs and requirements. US Space Command and the Air Force Space Command also have a formal method to prioritize requirements (the ADEPT process), however, the Air Force still separates the Need generation and Requirement generation processes.

The Organizational and Business Enablers are indicated below. Figure 73 is of the Organizational Enablers.

[48] For overall process maturity ranking, the three unified commands that did not contribute to the concept development and business case development phases, were given relative scores in those areas reflecting the primary service's input to that area. For example, USJFCOM was given the average score of the four services in each phase, while NORAD and US Space Command were given the US Air Force scores for those process phases.

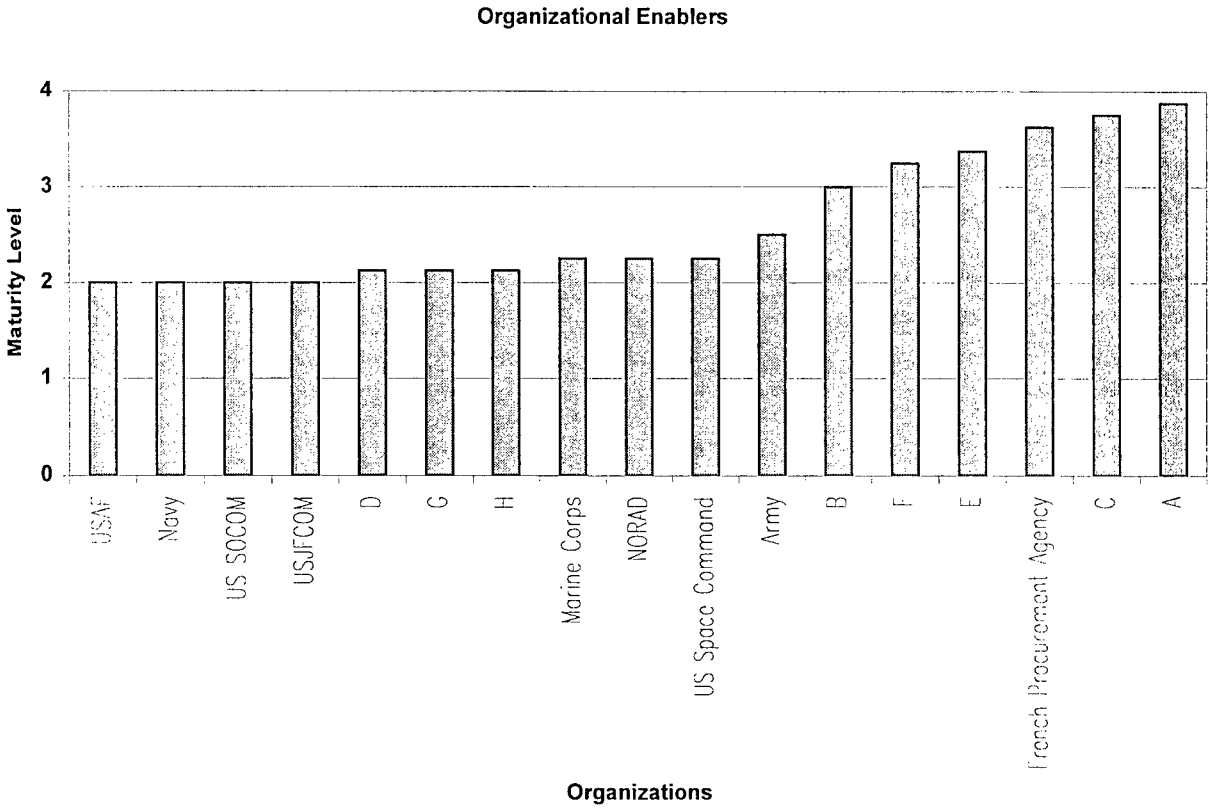

Figure 73. Organizational Enablers Outcomes

Every organization has achieved a fair level of organizational maturity. There are significant differences between the performance of military and commercial organizations in using organizational enablers. The average military organization is about ½ as good as the best commercial organization. Most of these differences are based upon the organizational structure used for the front-end process. The most mature organizations typically are team-based and draw members from a variety of cross-functional disciplines and other organizations with the enterprise to build front-end teams.

The Figure 74 displays the Business Foundation enabler outcomes.

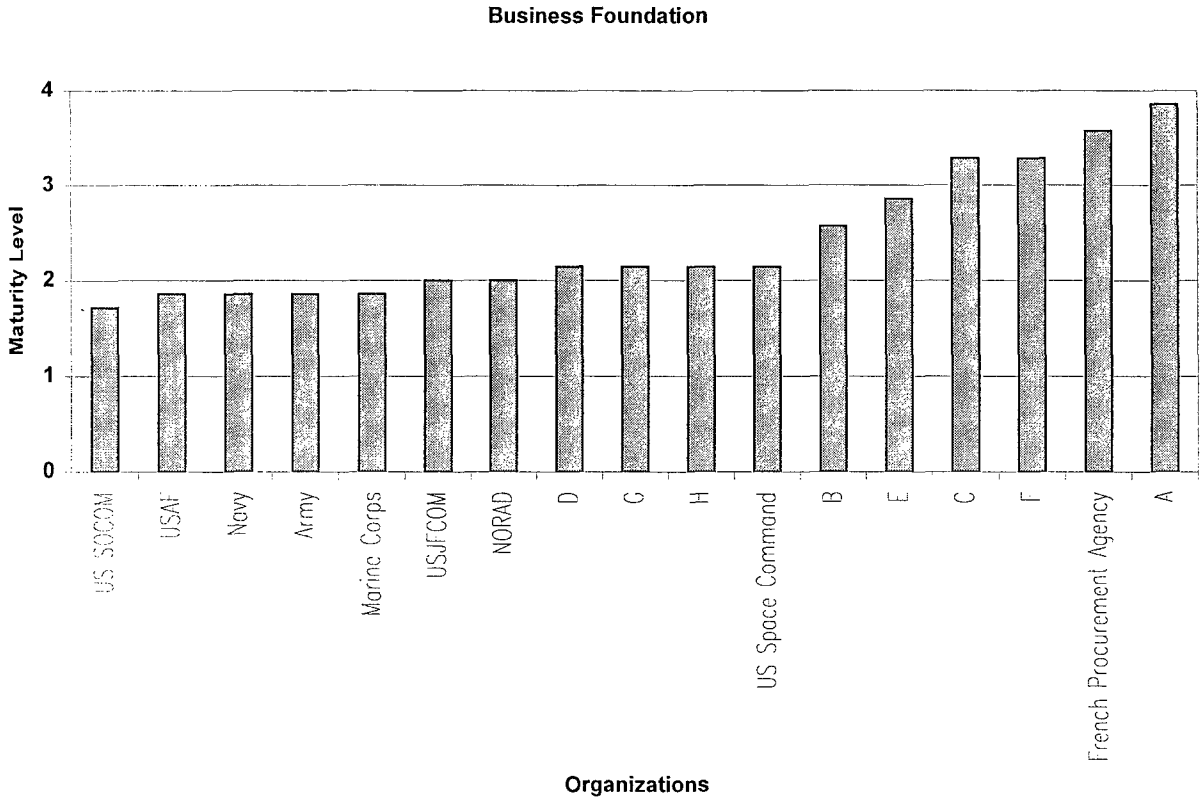

Figure 74. Business Enablers Outcomes

Business Enablers show distinct differences between the maturity of military organizations and commercial organizations, similar to that shown in the Organizational Enablers outcomes. Typically, the differences among the Business Enablers are highlighted in the separation between the 'requirements approval process' and the 'resource allocation process' in the military. Commercial organizations make no such separation; they are tightly integrated functions. Furthermore, the presence of an Information Technology tool that not only traces the development of the requirements but also includes decision aides and methodologies for all phases of the front-end process distinguishes a highly mature process. There are Islands of Excellence within some of the Military Services and also US Space Command uses such a tool in their front-end process; however, as US Space Command does not participate in all of the process phases, the tool's contribution to its overall process performance is muted.

Discussion

One of the hypotheses was that there would be a correlation between the process maturity of the Enablers and Enabling Practices to the front-end process outcome. Actual outcome measures, such as those of the previously identified metrics, to verify the validity of the front-end process, were not available for analysis. In some cases, there were no such metrics in place. This was particularly true for the military processes.

The Table 16 displays the correlation coefficients between the different phases of the matrix vs. those enabling practices and the p-value associated with the correlation coefficient. A p-value less than 0.05 is generally considered significant. Computed at the 95% confidence level, a p-value less than 0.05 indicates at least a 95% level of confidence (or higher) in the statistic being computed. Due to the small sample size, a p-value less than 0.1 will be considered significant in these cases. The results in Table 16 show that all of the process phases are strongly correlated.

Process Phase	Organizational Enablers		Business Enablers		Overall Enablers	
	Correlation Coefficient	p-value	Correlation Coefficient	p-value	Correlation Coefficient	p-value
Identification of Requirements Phase	0.69	0.0022	0.66	0.0038	0.68	0.0024
Initial Screening Phase	0.74	0.0008	0.83	<0.0001	0.79	0.0002
Concept Development Phase	0.68	0.0027	0.68	0.0025	0.69	0.0022
Business Case Development Phase	0.64	0.0061	0.67	0.0033	0.66	0.0040
Overall Process	0.77	0.0003	0.81	<0.0001	0.80	0.0001

Table 16. Correlation Coefficients and Their Respective p-values Among the Different Maturity Matrix Phases and Enablers

A closer look at the data reveals the existence of several data outliers in the Concept Development Phase and the Business Case Development Phase. First, Company D consistently performs very well in the individual phases of the front-end process. However, the company performs well despite lower process maturity among the Organizational and Business Enablers. The result is this company is a consistent outlier among the correlation data. Furthermore, this company is a software company. It is the only company with this profile. Further research should investigate if different types of industries

perform differently against the idealized front-end process and corresponding maturity matrix. Also, Companies G and H are in close proximity to company D. These two companies are from a different industry than Company D, but they are in the same industry among themselves, the airlines. Again, this prompts the question of whether an industry performs differently in relation to the maturity matrix and reveals a different type of response profile to the front-end process framework and maturity matrix.

The following charts present a closer look at the relationship between the individual portions of the maturity matrix and the enablers. Table 16 shows that there was virtually no difference in correlation between the Business Enablers and Organizational Enablers. Therefore, all of the following charts will use the Overall Average Enabler Scores. Not every pairing of process phases and enablers will be given; only those that can provide additional insight beyond the statistical correlation information in the table above are shown.

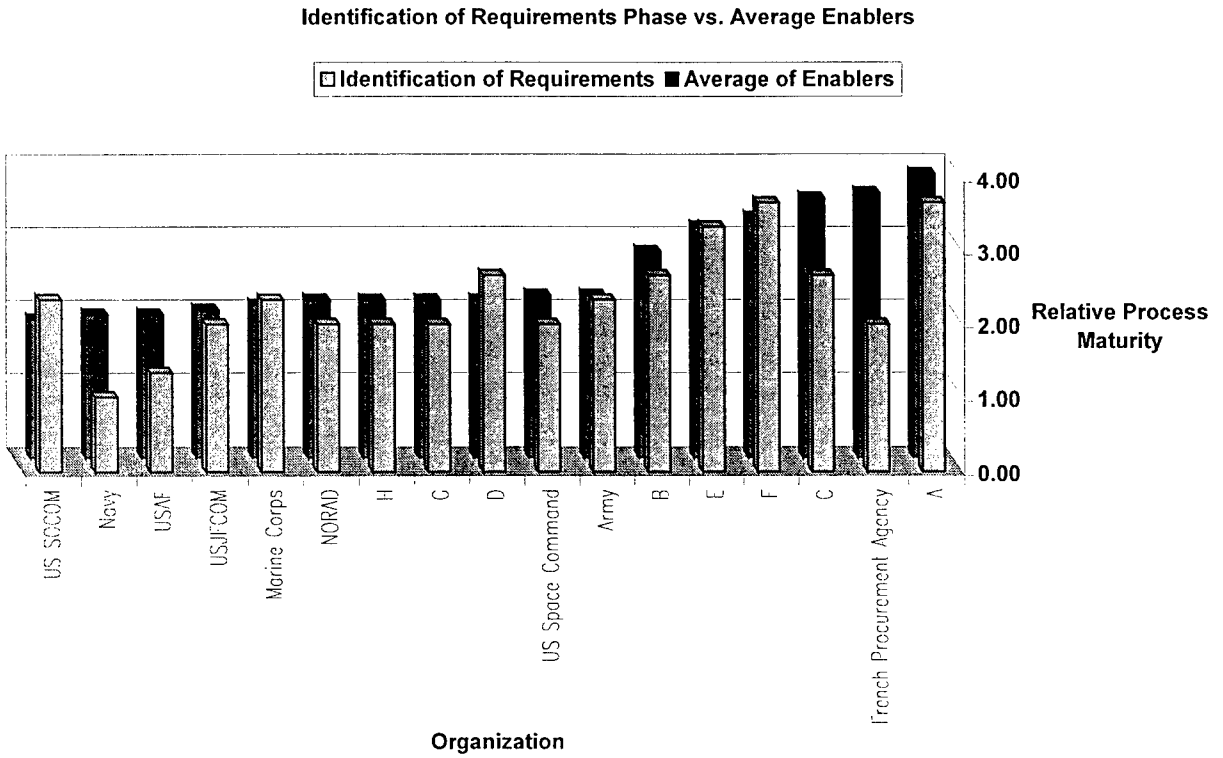

Figure 75. Outcome of Identification of Requirements Phase vs. Organizational Enablers

This figure is shown because it illustrates the process shortcomings of two US Military Services. In both of these cases, the Navy and the US Air Force have a process that is much less mature than those of the other services or military organizations. In both cases, the front-end is disconnected between the planning function of these organizations (where needs and/or requirements are initially identified) and their movement forward through the rest of the front-end process. The French have disconnected data as well. The explanation for the discrepancy lies in the way that it gathers needs and requirements – it relies heavily upon its customers (the warfighters) and the solutions are typically crafted in terms of a specific solution already envisioned by their customer. Company C is among the best performers in most process areas, in this case, the methods used to identify needs and requirements are not as mature as they potentially have the capability to be because the company relies upon the marketing department for its front-end inputs and closes out the possibility of other cross-functional inputs.

The Figure 76 shows the relationship between the Screening Phase and the Average Enablers.

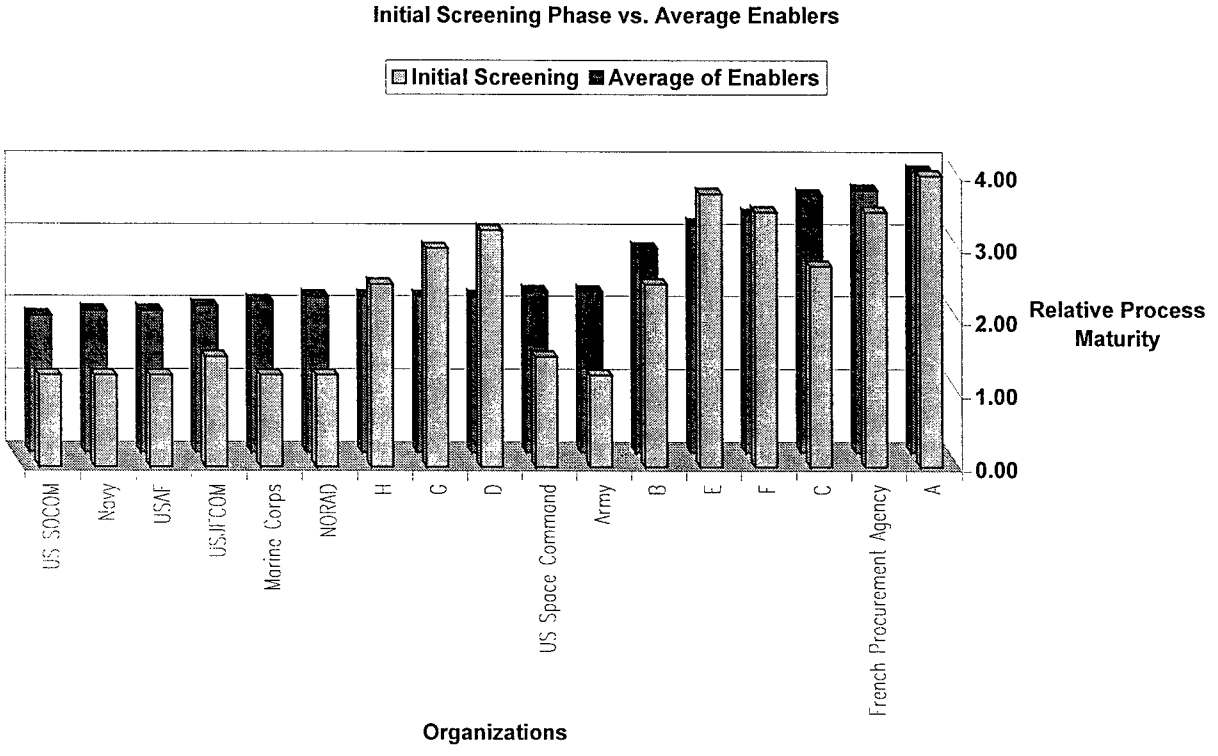

Figure 76. Outcomes of Screening Phase vs. Organizational Enablers

Figure 76 clearly shows that the current screening phase in the military front-end process is less mature than commercial counterparts (a fact underscored by the length of the current Air Force Process for the screening stage of over 400 days). The common traits of long cycle time and multiple level reviews is typical of all military organizations, with the exception of the French Procurement Agency. Additionally, there are many needs approved, but no resources allocated for their approval. In some sense, this stage in the military process really isn't an initial screen at all; it is primarily a consensus building exercise (albeit time consuming and expensive).

Company C's response reflects less process maturity due to the uncertainty involved in finding resources to further develop a need during the concept development phase. Company D has virtually no formal screen at all; certainly, it is not a formal process. Nevertheless, the company's structure

gives tremendous flexibility within general guidance to first-level employee supervisors that overcome its less mature organizational and business processes. Company B's disconnect comes from separate processes having a piece of this phase. Company G's disconnect comes from having just one organization responsible for the front-end process except for the business case development phase. The company's performance in this phase is better than its overall organizational and business process enablers would suggest due to that reason.

Recommendations for Further Research

Further research into this topic will help further the understanding and importance of the front-end of product development. There are several areas concerning the front-end process that have been touched upon only lightly and should be investigated more thoroughly.

One of the most important items for further research would be to assess the framework and the maturity matrix with outcome measures, including those referenced within the Idealized Framework. These objectives will likely be very difficult to achieve, especially in terms of the military and the huge time period required to navigate the front-end process. This difficulty is further compounded by the 'lack of definition' of many of the projects that undergo several iterations and name changes before moving on within the process. Among commercial companies, outcome information should be much easier to obtain as many of the identified metrics and process controls are already in place. Significant literature also exists on the performance of the front-end tying measures to existing organizational performance.

An additional step for further research would be to expand the sample size to a much greater size, targeting several industries (to investigate the possibility of different industry performance within the framework) and multiple organizations. This study should try to determine if things such as product complexity and technology influence an organization's front-end process. Additionally, other governmental agencies that are involved in product development, such as NASA, the FAA, the Coast Guard, and others should be included as part of this sample.

Requirements Management is a constant on-going issue with existing programs, particularly in military programs that take years to develop and field. Previous studies have indicated the importance of good

management of requirements, as they can contribute significantly to the cost and schedule growth that accompanies many programs.

Another area of research is the notion of 'Requirements Ripple'. This term can be defined as the effect that changing one requirement can have on the overall system and overall system requirements. This effect was encountered at one of the company sites during this research and the company indicated that a 'simple' requirement change, usually done at the request of a customer, can and often has unwanted and undesirable consequences. The company expressed interest in the delivery of a notional framework that would allow them to estimate the effect of requirements changes in terms of both cost and schedule. Such a product was beyond the scope of this effort, but one where the need is clearly expressed. The complexity of developing such a framework or tool for different requirement types is not known or well understood.

Another area of interest would be evaluating the organizational implications of constant reorganizations and its effect upon the front-end process of an organization. Company E practices this quite frequently, but the reorganization is expected and also a part of the company's culture. The US Military, on the other hand, is also known for its constant reorganizations. However, the performance of these organizations, in terms of the Idealized Framework, leaves much room for improvement. A study on the differences between these two examples would add a great deal of understanding to the theories behind organizational change.

Another area of study would be to pursue the cost of operating a front-end process, particularly the screening processes. Recent research indicates that the costs of a front-end process may actually outweigh its benefits (Reinertsen 1999). This implies the actual costs of running the front-end process as designed, to include personnel costs and research costs, may actually be more than the returns a project might provide an organization had there been no front-end process. Furthermore, this research distinguishes between types of screening processes found in the front-end. These screens can be extremely tough or relatively weak. A tough screen at the beginning of the process (and usually also the most expensive to operate), ensures virtually all projects proceeding from that point on are likely to make it to market (Reinertsen 1999). A second situation can have a relatively loose initial screening followed by an extremely tough second screen (similar to the Business Case Development Phase in the Idealized Framework). The variations in process design are too numerous to mention. However,

measurement of the outcomes of these different types of processes would contribute greatly to the knowledge about the front-end of product development and can lead to heuristics about when to use particular process designs over other alternatives. Again, the research indicates that the design of the front-end needs to be based upon economics (the investment required and also the costs to maintain and operate verses the overall returns) (Reinertsen 1999).

In terms of the US Military, it is difficult to quantify if its screening processes are really screens or just methods to build consensus. Rarely, if ever, will a program be cancelled following successful navigation of the overall front-end process (Hill, Jr. et al. 1986). Furthermore, the cost of the screens is likely to be huge and probably greater than first surmised. Analysis of these screens (and the overall process from an economic point of view (since the cost of delay is so difficult to measure in military terms)) could provide even more compelling information for the reform of the military's front-end processes.

CHAPTER 8 - CONCLUSIONS

The overall objective of this thesis, to find Best Practices for the front-end of product development through observation and correlation, has been addressed. These practices have been organized and presented in a framework of Best Practices for the Front-end of Product Development. A hypothesis throughout this thesis is that organizational and business enablers are required for an advanced front-end of product development. This hypothesis has been supported by the correlation between the Process Enablers and the Best Practices outlined in the front-end framework and maturity matrix. The framework and matrix is not all-inclusive; rather, it is hoped that the framework will provide organizations a starting point to better understand their front-end processes, their process performance, and ultimately their process outcomes. Furthermore, it is the author's wishes that the framework be considered a work in progress, awaiting the addition of further process knowledge, best practices, and understanding, whether gained through academic literature or actual experimentation.

This work began by illustrating some of the challenges and problems facing the US Air Force in developing needs and requirements for weapon systems. There are many issues that are probably coupled with politics and other factors outside of the control of the Air Force, but the discussion in this work focused upon those issues that most likely had a root cause in the process of developing needs and requirements; one that is not suited for today's environment. Clearly this observation is evidenced by the calls for reform and changes of these systems from within the services themselves and the commissioning of efforts to reform the existing systems.

The front-end process of the US Air Force and the US Military overall is similar to the current efforts of commercial firms to develop products quickly and effectively. This analogy allowed for the comparison of product development processes with the processes used in the military. Focusing upon the very initial stages of product development, this 'front-end' was analogous to the purposes of the planning and requirements processes of the US Military. The existing literature was probed for additional information regarding the front-ends of both the military and commercial processes in order to quantify and bound the area of interest. The various appendicies are designed to give greater depth and understanding about topics that are secondary to the purpose of this work, but highly relevant to

the overall understanding of the front-end process. To achieve the holistic perspective of the front-end, this information was added.

Highlighting the importance of the Front-end of product development, this work provides an organized framework to objectively quantify the essential elements of a front-end process. The front-end can be organized into a very successful and orderly process by which organizations can achieve substantial returns, both in terms of saved resources, but also great new products that serve the needs of its customers. The framework expounds upon the relevant literature and adds process metrics that will quantify performance of an organization's front-end. Additionally, the elements of the front-end process have been arranged in a matrix form to allow an organization to measure its relative process performance and identify areas to focus its improvement efforts.

The applicability of the framework was demonstrated by examining seventeen organizations, nine military organizations and eight commercial organizations. The military organizations came from every service, a representative combination of forces embodied in three unified commands, and also a foreign military example. This combination was to sample the various ways to approach the front-end in the military. On the commercial side, firms from various high technology industries to more traditional mass production industries were sampled, along with firms directly involved in the aerospace industry and the commercial defense industry. Again, this was done to approximate the wide variation of practices in use among commercial industry today.

Upon review, each of the US Military Services exhibited various "Islands of Excellence" that are laudable in their efforts and views of holistic thinking, such as the Army's use of the Integrated Concept Team, the Marine Corps (and Army's) WFLA process, the Navy's centralized process owner, and the Air Force's common IT tool (soon to be fielded). However, analysis of the information shows all of these efforts break down in the overall system process and contribute very little to overall process maturity - no more or less than other practices. Undoubtedly this situation leaves those working in these Islands of Excellence discouraged, particularly when these practices receive little or no recognition of their potential.

Although commercial organizations fare on average much better than the military in process performance and on their application of enablers, there are still substantial variations in process

outcomes. Nevertheless, the top performers were usually commercial organizations. Among the reasons top performers fared well in the analysis was that their front-end processes function according to the purposes of their design and encounter very few of the problems facing the military. These organizations typically have organized front-ends and are more holistic in their approach to product development. They seek to constantly improve their processes and place considerable importance of the front-end process on the future viability of the organization.

During the analysis, the maturity matrix was tested and the hypotheses about 'holistic' approaches to the front-end of product development built upon a solid foundation of Business and Organizational enablers were supported. Again, the results of this research only echo and substantiate what two special commissions on defense have asserted in the past about the importance of the front-end to the military's overall process (Gregory 1989).

The US Air Force and other military organizations' processes perform adequately. The achievements fostered by these processes are relevant. These processes enabled our country to win the Cold War. Later entanglements in Iraq, Bosina, and Kosovo have underscored the achievements of the current weapon system development process. However, the analysis clearly shows these processes could and should be improved. Clear recommendations to the US Air Force have been suggested that, if embraced, will likely require unprecedented changes in organizations and processes. Nevertheless, for radical process improvement to occur, these identified best practices must be implemented, as well as implementing the required organizational and business enablers, as soon as possible, to foster the process improvement.

As the budget available for the US Military declines proportionate to other areas of the US Federal budget, the message is more clear today than ever: the US Military must develop and field weapon systems faster, smarter, better, and cheaper than ever before. Without these processes and enablers in place, the US Military will find it increasingly difficult to maintain the superiority of arms advantage over its adversaries it has held for so long.

Eliminating the process disconnects, multiple handoffs and approvals, lack of authority and consensus building rather than effective decision-making must be done sooner rather than later. Currently these things represent waste – wasted time, resources, and opportunity. Building a systemic, holistic process

for the elucidation of needs and development of requirements for products (represented by the front-end process framework) embodies all of the tenets of a Lean process and represents the future of the Air Force.

Appendix A - Specific Practices proposed for the Front-end Process

The following paragraphs will outline many of the different practices espoused in the technical literature. The information presented here is not intended to be all-inclusive.

Front-end Process Capability Mapping

Khurana and Rosenthal were able to develop a classification scheme for the front-end of product development. They call their scheme a "front-end capability map". The first level is 'awareness', the second level is 'islands of capability', the third level is 'Integrated Capability'. In a sense, this classification scheme is similar to a process maturity matrix. The levels indicate what kinds of activities are taking place in each level and indicate what activities are required in order to be placed in a higher process ranking. For instance, the third level is where analysis and decisions have been both explicit and rigorous, and all front-end activities are managed as a single process (Khurana and Rosenthal 1997).[49] Achieving a balance between creativity and discipline is key to developing a competence in the new product development front end (Khurana and Rosenthal 1998). Companies using a 'map' according to the proposed heuristics can identify areas for improvement and concentrate their resources in those areas.

The Missed Elevator Approach

A valid concern of professionals in the New Product Development field is how keep up with and capture market information while minimizing changes in the product definition in relation to the mix of technology in the product. One study asked this question and identified what is called the "missed elevator" approach.

"The program manager realized that technological or feature enhancements for any product would never end. He required the product definition to include new features and feasible solutions to customer needs, as long as the planned milestone for that product release could be definitely achieved. If a customer need or technology-driven feature "missed the elevator," it would go into the next product release or "elevator." This approach to managing product development by having multi-release platform planning may become the next form of product development and management. Not

[49] There is a checklist for diagnosing the front end in (Khurana and Rosenthal 1997).

only does it help achieve a balance between stability and flexibility, but it also leverages technological strengths and organizational resources" (Khurana and Rosenthal 1997, pg. 110).

The Nyquist Theorem

This theorem is most usually associated with physics and the technical sciences. Surprisingly, an application has been found in the realm of new product development. The application is surrounding gathering the correct information from a highly dynamic system that is undergoing change. A prime application of this is identifying user needs.

"To recover the information in any given waveform, the sampling rate has to be at least twice the highest frequency in the waveform. The higher the rate of sampling, the greater the likelihood of recovering all the information. But the minimum rate is 2 times. Thus if a company has a system that changes monthly, it must sample at least twice a month to be confident that it is on top of developments within that system" (Patterson 1993). Or if threats change yearly, monthly, weekly, daily, the system must be sampled at least twice as often. The current AF system, using this analogy, "samples" yearly, and possibly every two years, depending upon the point-of-view (PPBS is a two year cycle).

Information Assembly Line

Ever since Henry Ford introduced the mass assembly line in his manufacturing processes, attempts have been made to adapt them to all kinds of systems. Product development is no exception. Patterson characterizes Product Development as an Information Assembly line. Just one extension of this thinking allows a Product Development Process to be evaluated in a similar fashion as the SEI (Software Enterprise Institute) Process Maturity Model. Just having a formalized documented process results in a Level 3 rating. The information assembly line can be seen using a 'value chain' or 'value stream' of processes (Patterson 1993). Mapping out process value streams in order to identify process improvement opportunities is a generally accepted method of process improvement. Additionally, Patterson includes a short discussion of other assembly line derivations and applications such as Information Theory considerations, Operations Management considerations, and general Management considerations that can help improve a process (Patterson 1993).

Organizational Competencies

Rosenthal, in his recent research, lists seven Organizational Competencies that are necessary for the fuzzy front end. These competencies are what are needed to routinely do successful front-end analysis.

1. "Formulating and communicating a product strategy (A product roadmap).
2. Planning a new-product portfolio. - (Planning competency to think in portfolio terms. Short-term vs. long-term time frame.)
3. Product approval leadership. - (Leadership should ask strategic questions and help steer them.)
4. Product concept formulation - (Prior to committing resources).
5. Stabilizing the product definition. - (Defining what you want to build.)[50]
6. Early consideration of supply chain factors. - (Before you even build the project.)
7. Sophisticated project planning. - (If it's not sensitive to technology issues, you introduce all sorts of risk. There are lots of contingency planning, understanding of variances in costs, schedules, etc" (Rosenthal 1998, pg. 11).

Cycle Time in the Front End

Patterson introduces the concept of the Innovation Life Cycle. The time 'T_o' is the 'time the opportunity for a new product occurs.' "It is a philosophical point in time, not usually discernible: the moment when emerging technology overlays a customer need and triggers a new product possibility. This definition is, of course, variable with circumstance" (Patterson 1993).

"Product innovation cycle time is the time between the moment when the window opens and the moment the first customers are satisfied. The opportunity occurs and generally is followed by some delay until time 'T_p' when it is perceived. It is business' job to reduce that delay time to a minimum and get a product into that window as quickly as possible" (Patterson 1993).

"The object of product development then is to identify opportunities, define the most competitive product possible and get the product to market expeditiously. Once the product definition is frozen, the primary factor that determines return on investment is the speed with which that product comes to life" (Patterson 1993). Requirements stability is very important. The basic idea is that if you can get things out the door sooner, the less likely you will need to change requirements. Waste coming from mid-stream changes will be much less if practiced (Patterson 1993).

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[50] For competencies 4 and 5, the issue is defining them, putting them into a process, and have people following it. Also, poor specification is the #1 cause of delay (unanticipated R&D spending).

"Reducing dead time is best achieved through effective strategic planning, market research, and technology research. Every business should - must, if it expects to be successful - maintain an on-going program which scans technological innovations, tracks competitors' activities, and actively pursues the perception of customer needs and expectations. This program should be operating in the background at all times and should be constantly comparing market needs with emerging technologies to perceive opportunities that are relevant to the business. This ongoing program is a relatively low-cost effort, probably the most cost-effective approach available for reducing the elapsed time between the time the opportunity occurs 'T_o' and the time the first customers are satisfied 'T_s'" (Patterson 1993).

Stages of Searching for User Needs/Requirements

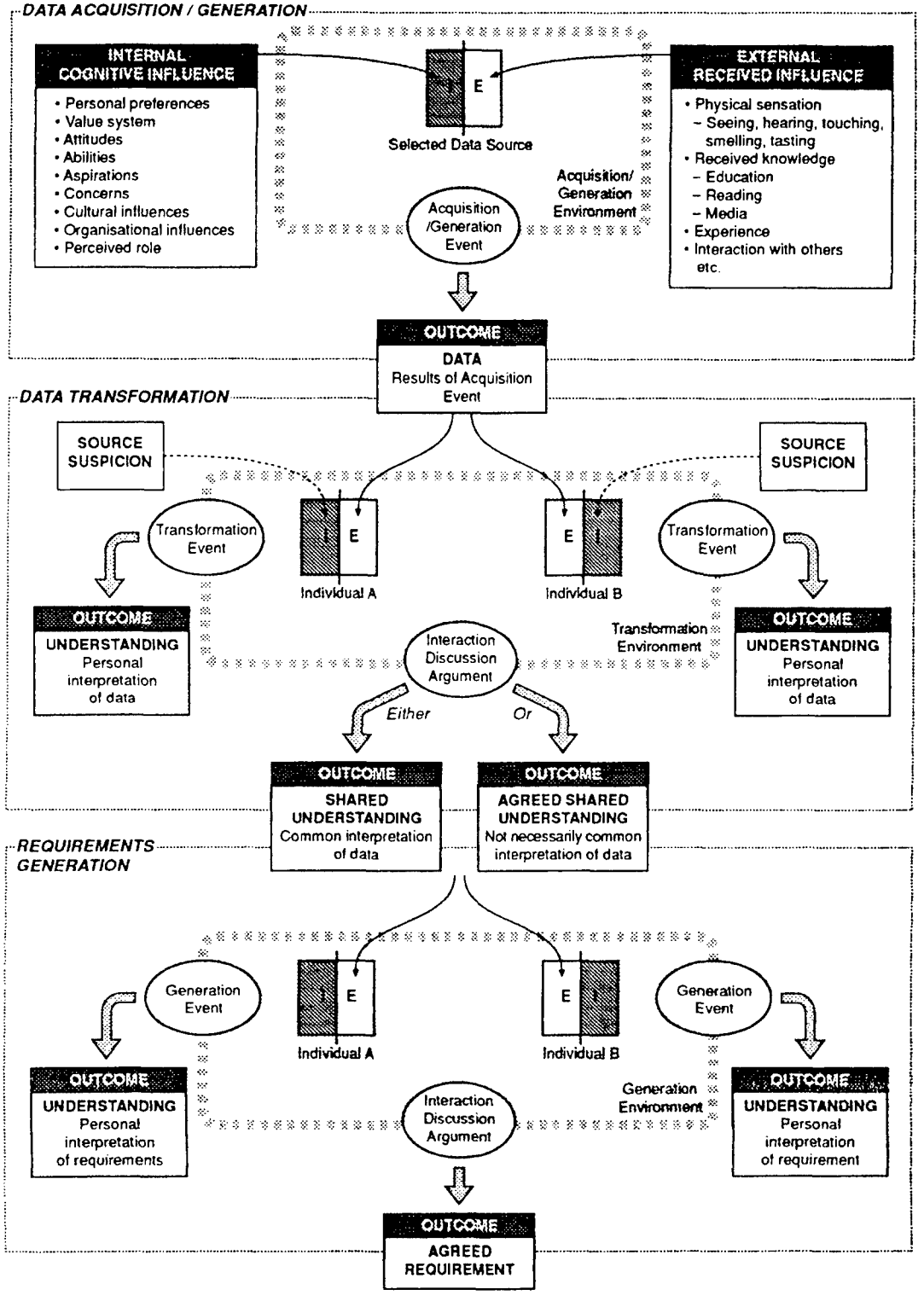
Conway and McGuiness conducted a study of nine firms that indicated that the development of new product ideas consists of three stages: the detection stage, the credibility-seeking stage, and the intensive search stage. "As a concept advanced through the process, it not only became more defined, but also, moved to becoming more and more of an organizational, rather than individual, priority. If accepted by the formal project development system, the developed concept becomes a formally funded organizational priority" (Conway and McGuinness 1986, pg. 285). Usually the detection stage consists of ideas shared by a few people or just an individual. These people understand the risks of the idea as well as how the idea is consistent with the strategic goals of the company (Conway and McGuinness 1986). Credibility-seeking simply means keeping the idea alive and broaden the circle of support; to some it means 'overcoming resistance' (Conway and McGuinness 1986). The Intensive Search stage is a formal technical and market analysis into the feasibility of the idea where company resources are expended to further develop the idea (Conway and McGuinness 1986). This stage gathers the information needed for the business case of the project.

Theoretical Framework to generate requirements from information

Cooper and Wootton developed a framework after studying the telecommunications, automotive and IT[51] industries. They indicate that generation of requirements has three parts: gathering of the information; transforming it; and generating the requirements (Cooper, Wooten et al. 1998). The main contribution of their work recognizes that "the derivation of any information that a source can give is

[51] Information Technology

the interaction of two separate factors: their internal cognitive influences (i.e. their preferences, beliefs, values and emotions); and their external received influences (i.e. their physical senses, education, received knowledge, experience)" (Cooper, Wooten et al. 1998, pg. 505). They further indicate that the environment that this information is received (hostile, friendly, relaxed, formal, etc.), impacts the outcome of these stages (Cooper, Wooten et al. 1998). When multiple individuals are involved in the generation of requirements, there is also the potential for misunderstanding. For instance, there can be Shared Understanding (a common interpretation of the data), or Agreed Shared Understanding (not necessarily a common interpretation of the data) (Cooper, Wooten et al. 1998). As the information is gathered, there is a 'transformation event' that occurs with each individual that then must be resolved through interaction, discussion and/or argument (Cooper, Wooten et al. 1998). This sequence of events also occurs during the generation of each requirement.



Source: (Cooper, Wooten et al. 1998)

Appendix B - Techniques to gather user needs and requirements

The next paragraphs illustrate the current methods employed by firms to gather user needs and requirements. These are not all used everywhere, but most commercial firms employ several forms to accomplish these tasks. Additionally, the Center for Innovation in Product Development (CIPD)[52] at the Massachusetts Institute of Technology has many research projects underway to expand the body of knowledge available to the practitioner about New Product Development. Highlights of some of their research efforts will be presented in the following sections.

Sources of ideas

The popular press has talked a lot about technology-push and customer-pull as being the sources for many new product development projects. Technology-push refers to the activity of an organization forcing technology into the product or an organization that actively markets technology for inclusion into a product. Customer-pull favors relying upon the customer to dictate the timing of new products (i.e. when and what). As these are somewhat ubiquitous no further discussion of these terms will be given. Conway and McGuinness add to these two types of sources four others. These categories are called: Market-Driven, Close-Follower, Planned-Diversification, and Opportunistic-Diversification. Market-Driven describes when problems or opportunities are discovered from serving a specific market and also understanding the needs of that market. Close-Follower describes problems or opportunities discovered by matching new products that are developed by a competitor. Planned-Diversification describes entering a new market specifically and strategically to diversify from traditional markets and/or products. Opportunistic-Diversification describes entering a new market, although the company had no intention of originally doing so. Of these processes, ¾ of the processes used by the companies in their study were market-driven or customer-pull (Conway and McGuinness 1986).

To bring greater understanding to the variety of techniques that are used to gather data, characterize it, prioritize it, optimize it, and finally test it, Dahan identifies several categories. Although his notional categories will be used in the discussion below, he acknowledges they are not all-inclusive (Dahan 1998).

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[52] CIPD maintains a World-Wide-Web home page. For more information, visit http://web.mit.edu/cipd/

Subject Matter Experts (SME)

This method consists of a knowledgeable expert in a given field. This person may be a current or past operator or customer of the firm or its products. The SME acts as a conduit of information for a developer of a product, process, or service, with which the SME has extensive experience. A good SME is able to articulate the knowledge he or she possesses in a manner that is not necessarily steeped in the language of the domain in question. In theory, this is not very difficult. In practice, this is one of the most difficult areas to master.

Lead Users

This is a form of innovation and discovery of user needs that the user does on its own. Lead Users are product users that have the motivation, drive, and technical know-how to improve upon or modify an existing product, process, or service to meet their needs and reap significant benefits (vonHippel 1988). Furthermore, Lead Users face these needs much earlier than the general marketplace will, usually on the order of months or years (vonHippel 1988). Therefore, identification of these Lead Users is essential in order to identify needs and have enough time to be able to produce a product, process, or service that coincides with the general marketplace's identification of a need (vonHippel 1988). An important point to remember is that Lead Users are not necessarily 'Early Adopters' (vonHippel 1988).

QFD

Quality Function Deployment can be used for many purposes. In the case of user needs, QFD is a useful tool. QFD is a method to take user needs and translate them into product, process, or service attributes. It uses a matrix form to relate the needs to attributes. The method also allows for conflicting attributes to be quickly identified for resolution. "The house of quality is a kind of conceptual map that provides the means for interfunctional planning and communications. People with different problems and responsibilities can thrash out design priorities while referring to patterns of evidence on the house's grid" (Hauser and Clausing 1988). "The driving force behind QFD analysis is a short, accurate list of key customer needs. These needs are related to product attributes that are then evaluated as to how well they meet the needs. Product attributes are also "benchmarked" against competitors' features weighted by their ability to meet customer needs better than those of competitors" (Dahan 1998, pg. 13). A study by "Jerry Wind and Vijay Mahajan that surveyed firms

about the needs-finding techniques they used when developing new products found that ... less than one in ten used Quality Function Deployment" (Dahan 1998, pg. 7).

Conjoint Analysis

Conjoint Analysis is a technique for prioritizing customer needs and preferences. It is extremely useful when the product, process, or service in question is selected based upon multiple attributes and the trade-offs customers make between them (Dahan 1998). These attributes are tied directly to customer needs (Dahan 1998). Additional variations to this method employ the use of orthogonal arrays or an experimental approach known as Taguchi methods (Dahan 1998).

Pugh Method

The method proposed by Pugh is one of concept selection. It is designed to identify those concepts with the best and strongest concepts. This method goes further by allowing specific product attributes to be identified according to strengths and weaknesses. This allows potentially new concepts to be conceived based upon the strengths of several competing others (Pugh 1996). The method works by first taking a well-established product as the Datum[53]. Competing new products are then scored against the attributes of this product with a simple plus or minus sign per attribute. These are then added and each new concept has a relative idea of how it compares to each of the other new designs and the Datum. "It pools the best properties of the several competing approaches to create a brand-new and even better approach" (Zangwill 1993).

Kano Analysis

Another method by which one can characterize customer needs according to their expectations is called a Kano Analysis. There are three levels of needs in the Kano model (Dahan 1998). First, a User Need can be characterized as a 'must have', where its absence will prevent the user from even considering the product, process, or service. Second, there are needs characterized by 'more the better'. Here, the need leads to greater user satisfaction the more the level of the attribute is present. Lastly, there are needs characterized as 'delighters'; needs that users don't actually expect to be fulfilled or are aware of. Delivery of these attributes becomes strong motivators for purchase and satisfaction.

[53] The reference point or data baseline.

Repertory Grids and Perceptual Maps

Additional ways to categorize user needs that have been gathered by various methods are using Repertory Grids and Perceptual Maps. They serve to identify common themes and patterns that exist in multiple user responses. K-J analysis is one example of this use (Dahan 1998). K-J analysis is a structured method to gather and analyze qualitative data when users can identify a product concept, but are unclear on the concepts important dimensions (Leonard-Barton, Wilson et al. 1994).

Empathic Design

Leonard and Rayport articulate the notion that sometimes users are not aware of their own needs (Leonard and Rayport 1997). "What customers can't tell you might be just what you need to develop successful new products" (Leonard and Rayport 1997, pg. 102). Either they have become accustomed to working with existing products or they don't realize that there could be an entirely different way of doing things or both (Leonard and Rayport 1997). The basis for Empathic Design rests upon observation of the customer in their natural environments. Five pieces of important information can be found through observation. They are triggers of use, interactions with the user's environment, user customization, intangible attributes of the product and unarticulated user needs (Leonard and Rayport 1997). Further the process usually encompasses five steps: observation; capturing data; reflection and analysis; brainstorming for solutions; and developing prototypes of possible solutions (Leonard and Rayport 1997).

Focus Groups

This method of eliciting user needs takes methods of interviewing and surveys and places it in a group setting. Here, it is hoped that the interaction among the different members of the focus group (its composition itself is worthy of study), will elicit ideas and needs in a manner that is much quicker than individual data gathering might uncover. Of course, some of the concerns deal with 'group think' that would eliminate useful ideas prematurely.

Interview and Surveys

These can be very effective in determining user needs, particularly for evolutionary designs targeted at an existing or familiar customer base (Dahan 1998). Griffen and Hauser have determined that "ten to twenty interviews per market segment elicit the vast majority of customer needs" (Dahan 1998). The challenges posed by this method is that it can be very time intensive, there needs to be an incentive for

the user to participate, and constructing the interview or survey questions can be very difficult. It is important to not introduce any bias into these questions (Dahan 1998). Also, capturing the actual 'voice of the customer' is critical as opposed to what the interviewer thought the interviewee said (Dahan 1998).

Cultural Anthropology

This is another term for design ethnography. It is closely related to empathic design. "Cultural anthropology is the study of hidden meanings underlying products, or meanings which are sought, but left unmet. The approach is broader than psychology-based motivational research in that it accounts for customers' social values, not just emotional needs" (Dahan 1998). Those that work in this field are social scientists, anthropologists and psychologists. They bring a disciplined approach to the field of new product development and help companies determine how people use their products (Takahashi 1998). It allows them to study relatively few subjects and focus on 'big insights' rather than statistical data (Takahashi 1998).

Toolkits

These are ways to facilitate user innovation and decrease the time required to move from requirements to production. Von Hippel, who also first identified the phenomenon of Lead Users, first noted the practice of using toolkits (vonHippel 1999). It was first used in the semi-conductor industry and has since spread elsewhere, such as the food service industry and also to commercial helicopter design (VanBuiten 1999; vonHippel 1999). For instance, master chefs are able to use toolkits to create food products and/or recipes that can be easily duplicated regardless of the abilities of the person preparing the food. This has far-reaching implications, particularly for chain restaurants, that want to ensure a similar and consistent customer experience regardless to which chain restaurant the customer frequents.

Appendix C - Tools and Technology Enablers for the Front End of Product Development

There are several enablers that are designed to facilitate good front-end processes. One such enabler is the tool used in requirements generation. Tools for requirements are varied. However, the common feature for all of the tools is that requirements are traced from conception or its source to its latest incarnation. According to Birkler, each of them has features and applicability that can be highly dependent on a company's overall processes and information technology philosophies (Birkler 1999). Each tool has its own strengths and weaknesses and requires a long-term commitment by a company for it to obtain the benefits of the investment (Birkler 1999). The following section gives an overview of some of the tools available. It is not intended to be all-inclusive list, or an analysis of the affectivity of these tools compared to each other.

IRSS

IRSS is a Booz-Allen & Hamilton developed tool designed specifically for the US Air Force's Requirements Process. IRSS stands for the Integrated Requirements Support System. It uses client-server architecture and can become an organization's information architecture - moving beyond requirements (Booz-Allen & Hamilton 1999). The system is organized around 'projects' which are the subjects of the Requirements documentation (Booz-Allen & Hamilton 1999). It also will correlate resources with tasks required for the project; it is a suspense-tracking tool (Booz-Allen & Hamilton 1999). All users of IRSS are able to connect with each other virtually and participate in the development of a project's requirements (Booz-Allen & Hamilton 1999). Lastly, IRSS facilitates the documented portion of a project's requirements. All documents created in IRSS are fully text searchable and accessible no matter the physical location of the document (Booz-Allen & Hamilton 1999). The US Air Force is scheduled to have this tool deployed to all of its locations by the end of 2000. Currently, the Army is using this tool and has given favorable feedback.

Caliber-RM

This has an object-oriented database that "hierarchically organizes requirements, with those requirements organized into projects that make up one or more sets or types of requirements" (Feibus 1998, pg. 1). It features requirements traceability and security, as well as interfaces to popular word

processing and database software programs (Feibus 1998). It also has add-on tools that will connect it with the Internet (Feibus 1998). It is in use by many aerospace companies.

IcCONCEPT RTM

IcCONCEPT RTM has a client/server architecture that "allows companies to automate the information-gathering and engineering processes, making it easier to capture and understand customer demands and concerns. The tool organizes this information, ensuring that product requirements are met in all phases of the development cycle - from product concept through product delivery" (Birkler 1999). Filling out computer-based forms captures information. End users, product development personnel, or anyone else the company has allowed access can do this. It is also in use by many aerospace companies.

DOORS

The acronym DOORS stands for Dynamic Object-Oriented Requirements System. This is another requirements management tool. It is able to be tailored to the customer's desires and has version control features, import and export links using standard interfaces into most software applications, and flexible reporting features (Feibus 1998). It also can be used on other operating systems like Unix (Feibus 1998). One add-on available allows the DOORS functionality to work through the Internet (Feibus 1998). "In Doors, requirements are called objects, which are grouped into modules, which are part of a project. Objects have attributes, which {can be tailored} to the needs of a specific module ... Module and requirement change history are maintained for auditing purposes, and ... baseline versions of entire modules for tracking module revisions" can be created (Feibus 1998). The system can be accessed through a network and maintain thousands of links and objects (Birkler 1999). It also will ensure compliance with the ISO 13485 quality control standard (Birkler 1999).

Executive Management Information Systems

These are tools used by upper management and executives to keep pulse on their organizations. There are several of these available commercially and will not be reviewed here. They are tools such as ERP[54], SAP, etc. One such tool is Expert Choice. This tool is based upon the use of two processes. These are the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) (Expert Choice 1999). AHP is a methodology developed over 20 years ago and is used for complex, multi-

[54] Enterprise Resource Planning.

criteria problems where both qualitative and quantitative issues must be addressed (Expert Choice 1999). ANP is an extension of the AHP methodology. It incorporates feedback among the different problem elements as well as any dependencies that exist between them (Expert Choice 1999).

DOME

DOME is a tool developed by MIT's CIPD that strives to reduce the time to design new products. DOME stands for Distributed Object-based Modeling Environment. "Dome provides the framework that permits the experts involved in designing a new product to use the various software tools, models and data most appropriate for each area of expertise, yet still allows rapid exploration of the tradeoffs of different design attributes" (Wallace and Wang 1999, pg. 1). The biggest contributions this tool makes to New Product Development comes through creating a common interface to already existing software tools used ranging from word processing files, to spreadsheets, to detailed drawing packages. It also facilitates the ability to quickly assess alternatives (Wallace and Wang 1999).

Appendix D - Observations about the PPBS and the US Air Force

The combined outputs of each individual MAJCOM's Planning Process produce a fiscally unconstrained list of needs. In the aggregate, the sum total of these outputs would increase the AF budget beyond what the budget can sustain. This problem persists even when assuming a 10% growth in the current funding levels. For example, according to one source within the Air Force Acquisition Office, in any given year, a particular item can be the number one requirement for a MAJCOM. Efforts are made to secure funding, and once this occurs, it drops on the priority list. Perhaps this is due to rotating leadership, or action officers 'trying to push their program through' so they can get a good performance evaluation, or other reasons, or simply acknowledgement that this is the only way for programs to get the funding they need. When things drop in priority, this introduces 'turbulence' and more chaos into an already turbulent system. Often, the reaction of the system is to delay, modify, and/or change the program in question to remain viable. Furthermore, it is well known that once funding is secured, it is very difficult to turn off that funding (Hill, Jr. et al. 1986).

Additionally, no one really knows how effective the Modernization Planning Process (MPP) is. Interviews with 15 participants in the process indicate a general consensus that the system is "broken" or "too slow". However, there is little quantifiable data to validate this perception. Air Force Policy Document (AFPD) 10-14, Modernization Planning, released in 1995, mandates the use of the 'Strategy-to-task' philosophy and also mandates the use of a metric to evaluate the effectiveness of the MPP (USAF 1996). This metric is defined as the number of MPP products that are placed into the PPBS. Contact with AF officials in the Pentagon Strategic Planning Directorate indicates that this information is not being collected by the Air Force and that the Air Force policy document is in the process of being rewritten to remove the measurement requirement.

The products of the MPP process emerge after 1 1/2 years to 2 years within the system. This does not include the delays then encountered by the Requirements Generation System and also the PPBS. All of these processes are serial in nature, although efforts are made to run these systems in parallel as much as possible. The time period mentioned earlier is now the usual norm. An additional 1 to 2 years is usually required to get through the other systems.

The second step of the PPBS, Programming, begins as the MAJCOM individually rank-orders the potential solutions listed in the MAP, in order of preference, in its Programming (POM) and FYDP inputs. It should use the MAP to develop the POM for the MAJCOM. Any programmed item that is new must be documented in a Mission Area Plan as per AF Instruction 10-1401 (See also USAF 1996). The AF then shapes an overall plan from all of the MAJCOM inputs and determines which projects to place in the AF POM and FYDP. This is done as the Air Force builds its PPBS documents (POM, BES, etc.) through a series of reviews. Hard decisions must be made at every step to determine where the scarce resources should be allocated among the different requests. The MAJCOM inputs are passed by various Program Element Monitors[55] (PEMs) to one of 14 Panels that are organized according to Air Force mission and core competencies. Integrated Process Teams (IPT) that seek to balance programs within the panel's area support the Panels.

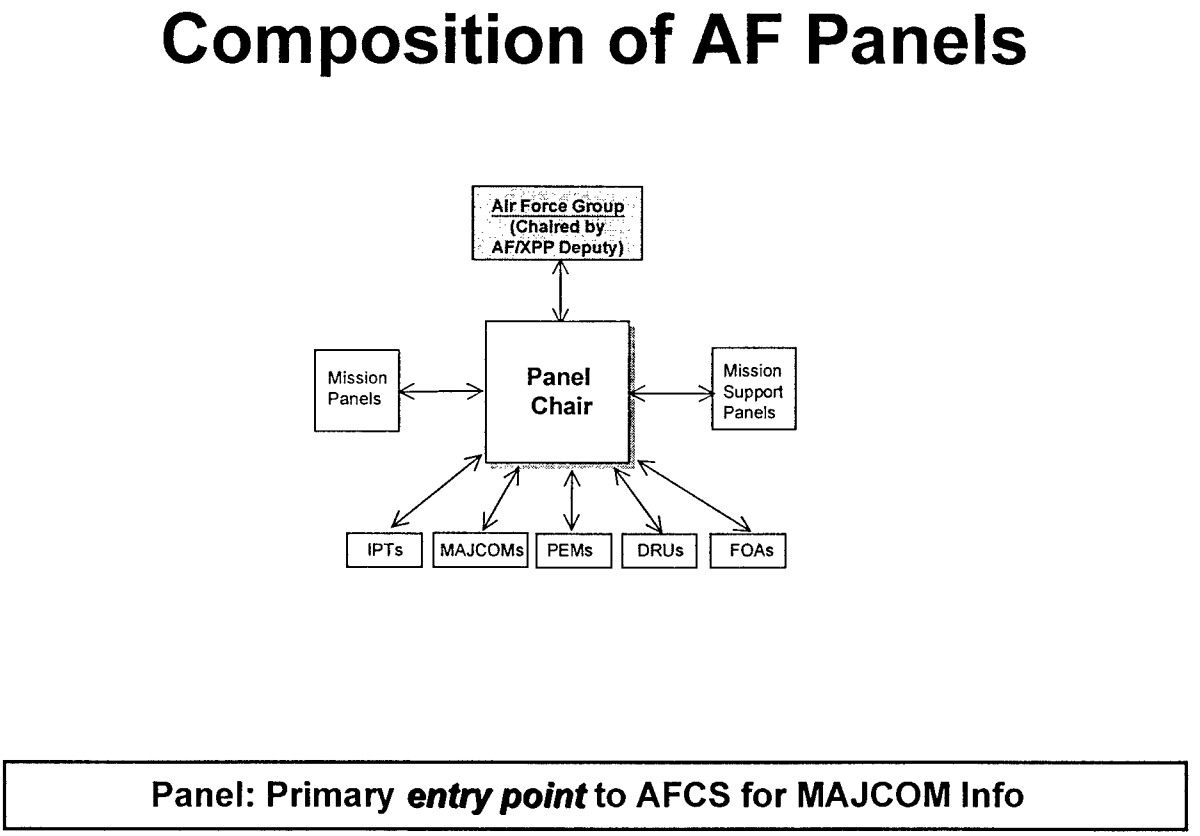


Figure 77. Composition of the Air Force Panel (Plummer 1999)

[55] These individuals concern themselves with the fiscal accountability of moneys used by weapon systems in particular mission areas.

Upon completion of their work, the next review committee is called the Air Force Group. They analyze and resolve decisions made by the different panels. This is the first time there is a corporate look at the entire integrated Air Force proposed program. The next step is done by the Air Force Board that resolve other issues not done by the Group. The last step in the process is a review by the Air Force Council. The members of this council are the staff members of the Air Force Chief of Staff and the Secretary of the Air Force. The final approval comes from the Chief of Staff and the Secretary of the Air Force (Plummer 1999). The people making these decisions are not a part of the Requirements Generation System; nevertheless, they end up making decisions and trading-off requirements in their effort to put together a balanced, fiscally constrained financial plan.

Air Force Corporate Structure

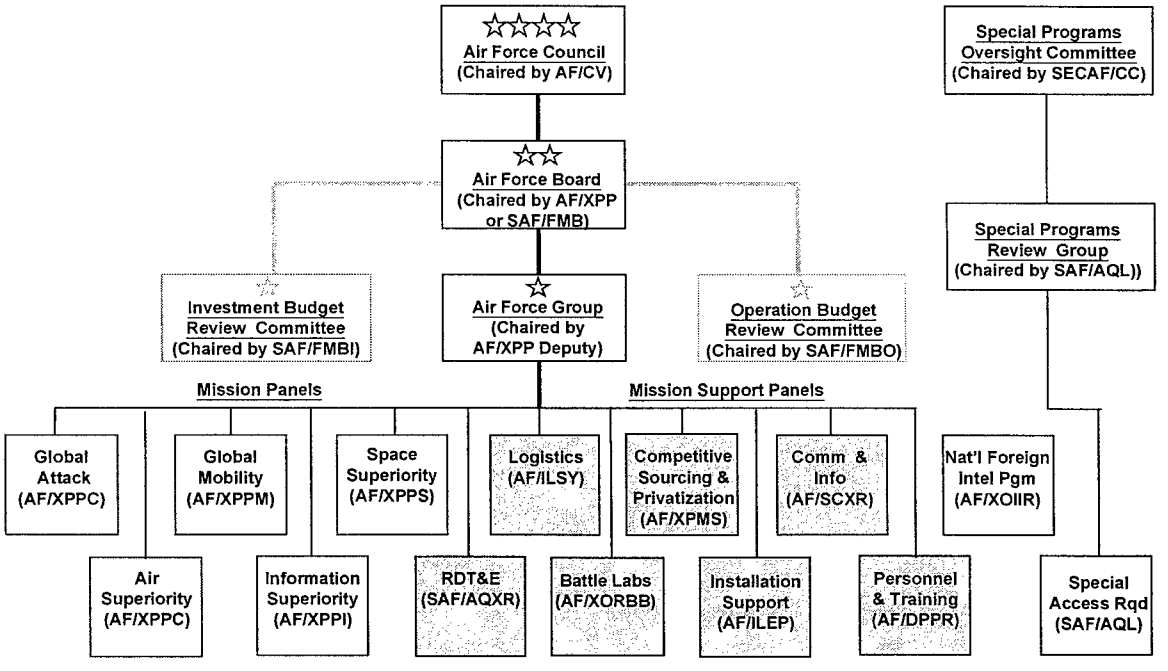
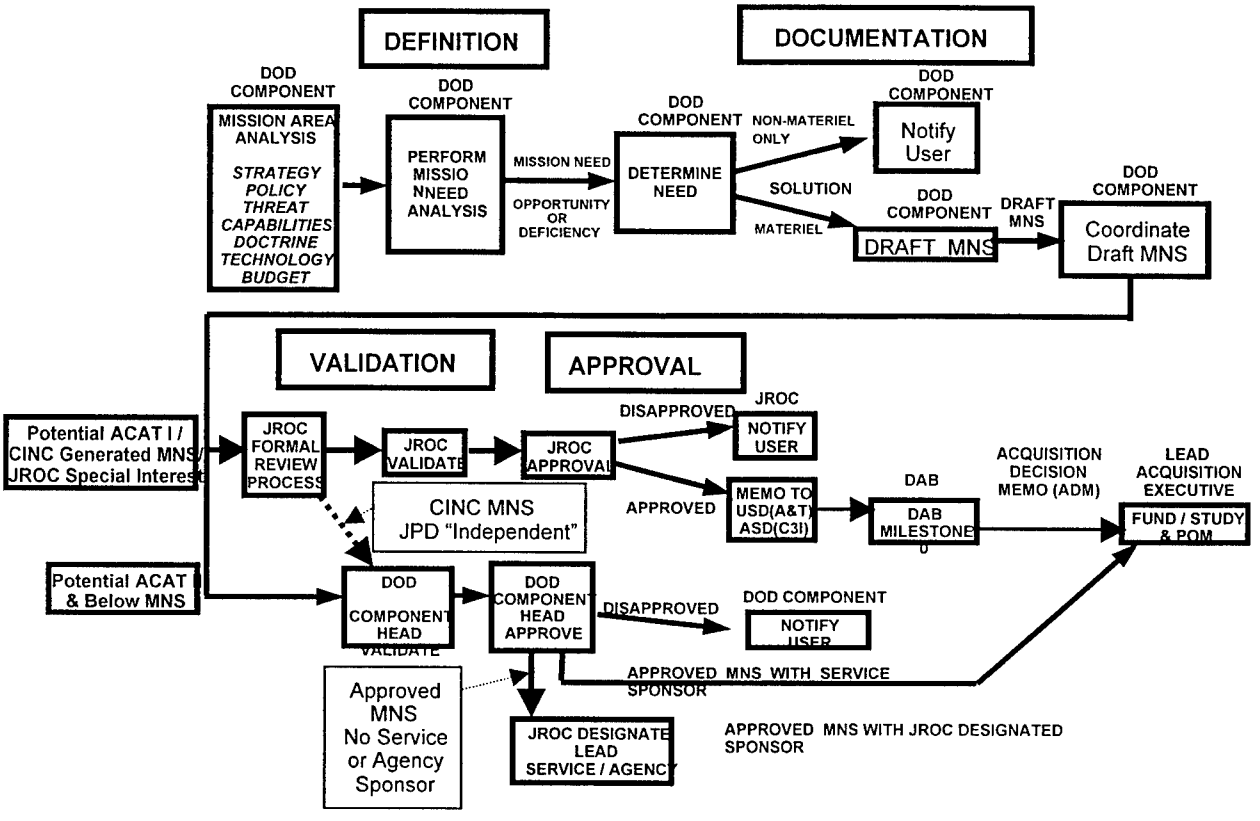


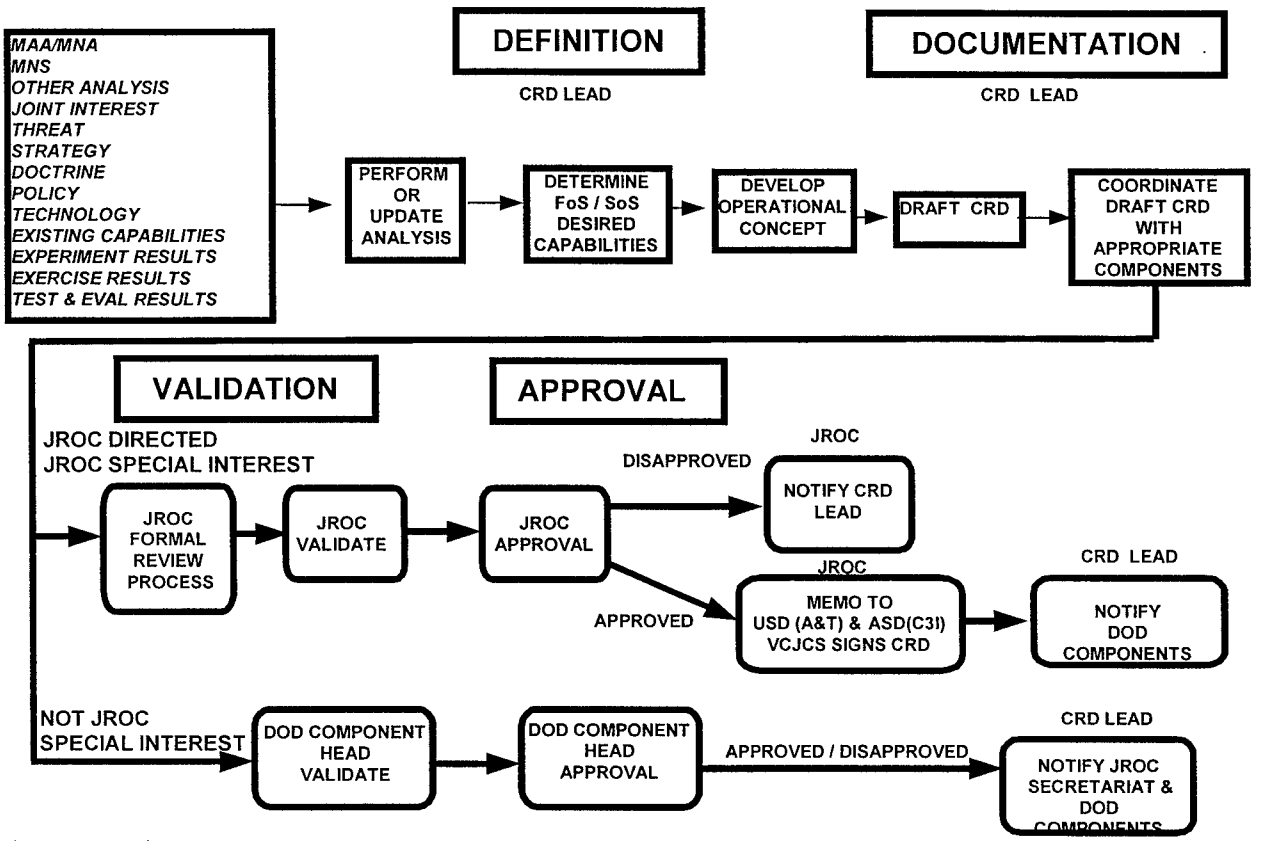
Figure 78. Air Force Corporate Structure (Plummer 1999)

Appendix E – Generic (Non-Service Specific) Requirement Document Generation Process



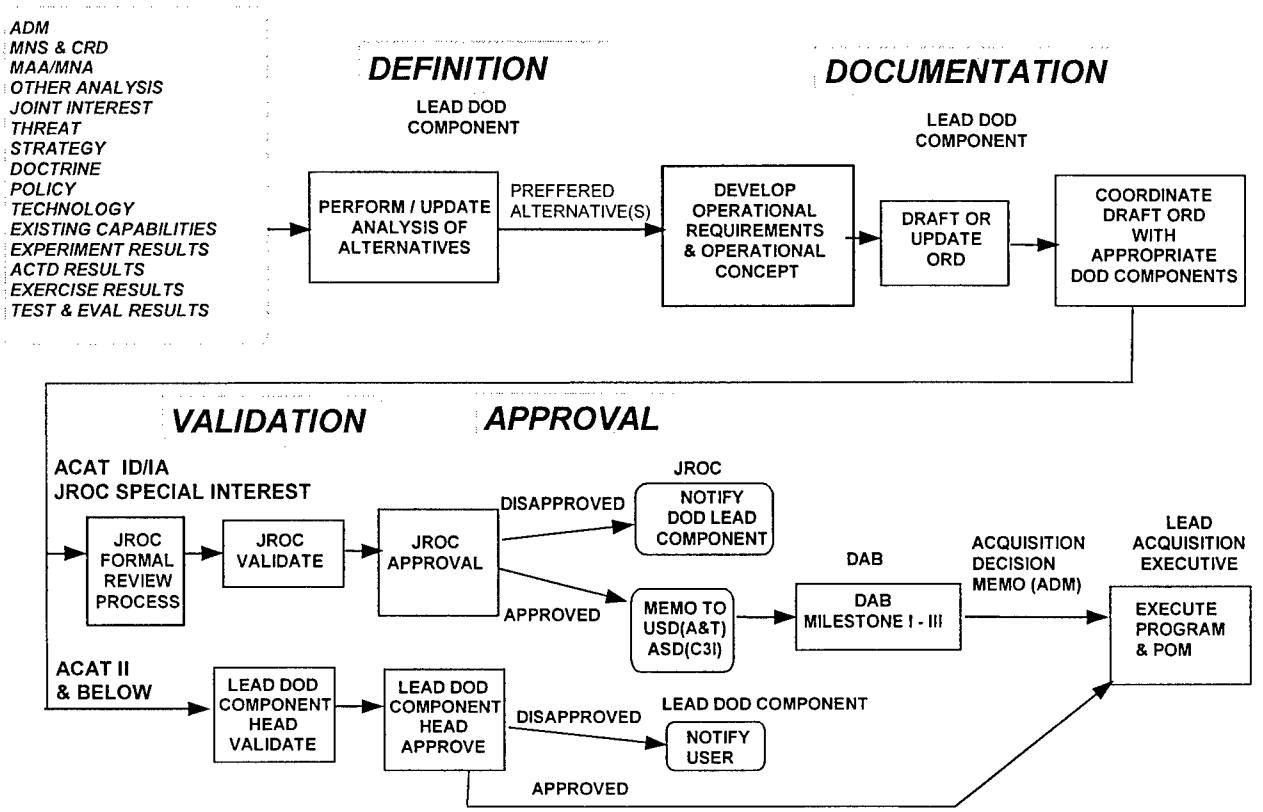
(CJCS 1999)

Figure 79. Generic (Non-Service Specific) Mission Need Statement Generation Process



(CJCS 1999)

Figure 80. Generic (Non-Service Specific) CRD Generation Process



(CJCS 1999)

Figure 81. Generic (Non-Service Specific) ORD Generation Process

Appendix F - Details about the Acquisition System in the Air Force

The Acquisition System of the Air Force does not differ substantially from the general process outlined in the section in Chapter 2. The activities of the acquisition system for the Air Force in the pre-milestone zero phase are limited to the interactions of Technical Planning Integrated Product Teams with those conducting Mission Need Analysis studies and Mission Solution Analysis studies. The TPIPTs interact with them as well as the labs and other sources of new technology. They often participate in the technical evaluation of new concept ideas and potential solutions during this time. Additionally, cost analysts help evaluate projected program costs and support the TPIPTs.

Participation of Acquisition personnel in Phase Zero is usually limited. The Organization of Aerospace Studies (OAS) is an organization that develops and promotes 'Best Practices' in conducting Analysis of Alternatives. They do not run these analyses (the MAJCOMs do), but they serve as consultants to the process.

Should an existing weapon system be the source of a new requirement, the process requires it to go through the full-blown weapon system development process of drafting, validating, and approving a Mission Need Statement and an Operational Requirements Document. Therefore, in this case, the System Program Office will be active during the first two phases, simply because of the relationship it has with the new system. Nevertheless, the SPO will be active only in a secondary role – the user is still responsible until reaching Milestone I decision (although the user may ask the SPO to run the AoA on their behalf).

Finally, Air Force laboratories are considered part of the Acquisition System and participate in the process by furthering research into those areas identified by the warfighter, in conjunction with the TPIPTs that demand further development.

Appendix G - Proposed improvements to the current Air Force system

Now that the current system has been explained and put into perspective, there are efforts underway to change the system - partly as a result of the previously identified problems and also in a desire to improve the system. Interestingly, the vast majority of these efforts are in the realm of strategic planning - where user needs are initially identified. If the best place to influence the outcome of a system is at the front-end, then this is the most logical place to begin reforms.

One study framed the issues with the following introduction. "Ideally, broad thinking about how specific missions might be accomplished should precede decisions about what kinds of platforms, what classes of technologies, or which military service is most appropriate for particular tasks. Too often, however, these steps in the process of planning force modernization are reversed. As a result, concept development sometimes becomes more an exercise in finding a use for a given technology, platform, or operational method rather than in finding the right technology or platform to perform a specific function. Thinking about alternative options is narrowed, and competition among alternative concepts is weakened" (Birkler 1998, pg. xi).

"Given this context, as one thinks about approaches to force planning methods, three principles should be kept in mind:

- Traditional "threat-based planning," the stalwart of defense planning for decades, is no longer an adequate basis for mid- and long-range planning (see, e.g., Secretary of Defense William J. Perry's 1996 report to Congress). Focusing on a few point scenarios suppresses too many issues
- National security planning should instead confront head-on the reality of substantial uncertainty in many dimensions, political and strategic as well as purely military
- Planning activities should be forward looking: They should focus on the long term, and they should encourage examination of options for changing strategy, forces, and doctrine" (Davis 1996, pg. xi).

The following excerpts from papers, reports, and articles summarize some of the existing proposals to change the way strategic planning is done within the military. They all have very relevant points and address real issues seen as drawbacks in the current system.

One paper suggests a total reorganization of the Office of the Under Secretary of Defense for Acquisition and Technology. The reason is: "the office has not changed in the face of several DoD initiatives in such areas as greater use of commercial technology, lean production, outsourcing, and joint warfare" (Bracken, Birkler et al. 1996, pg. v).

The principle argument is that structure should match strategy. One option that is particularly aggressive is for the creation of a structure with the following parts:

- "A science and technology office with a broader charter than the current one.
- A concept development and joint integration office with a charter to formulate, evaluate, and define concepts in each mission area. This office would be organized around two themes: operational concepts and system concepts and their demonstration.
- An acquisition office, which would oversee platforms and systems. This office would be organized according to type of platform" (Bracken, Birkler et al. 1996, pg. v - vi).

Still another study recommends major changes that would de-emphasize the "deliberate planning system," elevate the importance of "crisis-action planning," and use frequent, rigorous exercises to test and refine the ability to develop and execute in the development and creation of appropriate plans in crisis (Davis 1993). "The approach would depend on building-block methods that are quite comfortable to many American military officers, and which, indeed, can already be seen at work at lower levels of organization. ... The study also recommends that strategic and programmatic planning be changed in ways that would be more consistent with planning under uncertainty and encouraging flexibility and adaptiveness rather than optimization for well-defined scenarios" (Davis 1993, Abstract).

Another strategic planning methodology RAND has developed over the last four years is called Assumption-Based Planning (ABP). The five steps of the methodology are (1) identifying important assumptions underlying an organization's operations or plans; (2) identifying assumption vulnerabilities within the planning horizon; (3) defining signposts (i.e., indicators or warning signs of a change in an assumption's vulnerability); (4) defining shaping actions (actions taken to avert or cause the failure of an assumption); and (5) defining hedging actions (actions taken to better prepare for the failure of an assumption) (Dewar 1993). The report compares ABP with other methodologies. It argues that "the methodology provides a systematic way of thinking about and dealing with a future containing fundamental uncertainties about an organization's ends"(Dewar 1993, pg. 57).

Another report sponsored by the United States Military Academy's Department of Systems Engineering tried to attack the fiscal problems created by an unconstrained front-end. The purpose was to develop methods for assessing capabilities of alternative force structures for warfighting and non-warfighting missions. This methodology also assesses joint force structure based upon

warfighting requirements. The report is an attempt to develop a methodology that will provide some analytical rigor to the process. An integer programming (IP) model is used to make force-unit trade-offs, using Mission Capability Packages' (MCP's) as building blocks. "The IP model, which may eventually evolve to a generalized mathematical program, determines efficient (i.e. non-redundant and effective) force mixes to accomplish given missions. In the model, MCP's are defined as integrated slices of the total force required to accomplish assigned missions" (Farr 1994, pg. i). The Army has tried to implement this model in the WFLA process and other selective areas. Results have been inconclusive to date.

Air Combat Command has recently introduced a similar tool called the Modernization Investment Plan or MIP. Specifically, it is a goal programming tool that "links investment strategy to HHQ and CAF guidance; analysis of our needs; and capital budgeting activity. It includes {sic} decision support system as part of the process to aid programmers. It contains visible program interdependencies and has understandable implications of iterations" (Todd 1997). It has a mathematical program at the heart of the tool. One Air Force official indicated that before the use of the MIP, ACC was hitting the 'target' about 5% of the time. With the MIP, that percentage has increased dramatically (O'Riordan 1998). Ostensibly, hitting the target refers to the way ACC allocated its resources. These cited percentages meant ACC was programming and budgeting in a way that rarely focused those scarce resources on the real issues. Now, that ability seems to have improved - although the amount of improvement is difficult to quantify as those interviewed expressed a range of answers (from 25% to 75%). The true impact of this tool remains to be seen, especially with the variability of rack and stack lists and impacts of 'commander's discretion'.

Another RAND study was completed to assist the Air Force in defining a new concept development framework and process that could support Air Force long range planning. RAND proposed the creation of Concept Operations Groups to support Air Force planning. It also proposed ideas for how the Air Force might proceed with institutionalizing the framework and process (Lewis 1995). This appears to be a further derivation of the TPIPT process.

Smith proposes conceptual Changes to the process. There are seven changes that he suggests to the current process. First, an acquisition professional should be placed on the combatant commander's staff to provide the CINC with more acquisition expertise. Second, the CINC should have the

authority to submit a Mission Needs Statement directly at any time, not just during times of conflict. Third, mission area analyses should be mandated parts of after-action reports of exercises and conflicts. Fourth, commanders should be able to advise on the technology plans of the services. Fifth, the CINC's staff should be allowed to prepare or coordinate on Analysis of Alternatives, Operational Requirements Documents, and Requirements Correlation Matrices. Sixth, test schedules should be timed to coincide with exercises so that concepts can be exposed to approximated operational experiences. Seventh, use the Joint Warfighting Capabilities Assessment (JWCA) forum as the foundation for Mission Needs Statements. He cites the experience of US Special Operations Command (US SOCOM), with acquisition authority, as proof that these changes have already brought about the desired effect in SOCOM (Smith 1999).

Appendix H - Why the current air Force system exists

To truly gain an understanding of the military system, why it exists in the form it does, and functions in the manner it does, a review of the foundational history was undertaken. One author more than any other has helped put into perspective the current realities of the system. His insights are as applicable today as they were in 1953. Mr. I.B. Holley, an Air Force historian, wrote three papers about the acquisition and development of weapon systems. These papers were based on his experience during the last 18 months of World War II and a few years afterward. These studies had a common theme that led to the publication of his book. He observed that "the pace of development for any weapon system during the between-war years is chiefly determined by the extent to which it's mission or operational function is known and defined. When there is no effective system for determining doctrine, the pace of development is necessarily slow" (I. B. Holley 1953, pg. vii). Mr. Holley succinctly describes the situation that existed in the early history of the US Air Force and actually had its roots in the military in general.

In his study of Air Force history he reveals "three specific shortcoming{s} in the procedure for developing new weapons. These shortcomings appear to have been: a failure to adopt, actively and positively, the thesis that superior arms favor victory; a failure to recognize the importance of establishing a doctrine regarding the use of weapons; and a failure to devise effective techniques for recognizing and evaluating potential weapons in the advances of science and technology" (I. B. Holley 1953, pg. 10).

Do the three shortcomings still exist in the military today? What lessons might be learned from this? This author's judgement maintains the first shortcoming no longer exists in the Air Force today. Today's Air Force is built upon the premise of 'superior arms' and/or technology. However, the second shortcoming clearly exists. The Air Force only recently (February 1997) established its Doctrine Center at Maxwell AFB, AL (Michael 1999). Although nearly 40 doctrinal documents have been issued by the center, not enough time has elapsed since its inception to quantify the impact of the center on doctrine and weapon system requirements/development related issues. The third shortcoming also exists. Here the key is in the term 'effective'. As a recently completed study of the Air Force Requirements Process indicated: the Air Force "lacks effective guidance, analysis, and training, causing problems with linkages to other core processes, resulting in an unnecessarily

bureaucratic process that is ineffective in garnering and sustaining program support" (HAF/XORD 1999).

The link between doctrine and new technology is often overlooked because the existing process to develop weapon systems does not include it. "It is not surprising that the problem of relating doctrine to technological advance in weapons received only belated attention, in most instances long after the weapon itself had become available. ... The greatest stumbling block to the revision of doctrine was probably not so much vested interests as the absence of a system for analyzing new weapons and their relation to prevailing concepts of utilizing weapons" (I. B. Holley 1953, pg. 15).

Again, the recently completed study of the Requirements process indicated that the Concept of Operations or the Concept of Employment was the single most important part of defining the correct requirements for the operation of the system (USAF/DXOR 1999).

The history of the machine gun, tank, and gas warfare shows "that the pace at which weapons develop is determined by the effectiveness of the procedures established to translate ideas into weapons" (I. B. Holley 1953, pg. 19). This simple statement implies the importance of 'the entire process', and how it drives weapon development.

The Army had two factors in the Civil War era that contributed to failure in these areas. "The first factor was the apparent inability of the successive authorities to establish either a sound organization or effective administrative procedures to accomplish the desired task. The second, the pressure of an obvious need for standardization in opposition to the continual pace of technological development" (I. B. Holley 1953, pg. 19). Do these problems exist in the Air Force today? There is constant organizational turbulence and changing guidance. Ever since Dr. William Perry as the Under Secretary of the Air Force for Acquisition launched Acquisition Reform with the Mil-Standard and Mil-Spec reform (in 1993), there has been almost constant churn in both organizations and procedures. Furthermore, ideas such as platforming and design reuse, software reuse, etc., continue to gain momentum and importance, although their impacts to organizations and procedures remain unquantified.

In general, the "experience of the {Army} department demonstrated the importance of establishing a concept of requirements, the military characteristics of a weapon, before beginning development.

Similarly, experience had shown the importance of differentiating a good idea from the failure of that idea in a specific application" (I. B. Holley 1953, pg. 21). In essence, the Air Force also understands these axioms with their employment of a Mission Needs Statement, an Operational Requirements document (with accompanying Concept of Employment), and also a formal Analyses of Alternatives.

Air applications in WW1 were interesting to note. The "Chief of the Air Service, AEF[56], emphasized the critical importance of progressive development of design in maintaining a force of aircraft superior to that of the enemy on the front. An aircraft, which dominated the air one day, he reported, might be "totally obsolete" six months later. Superiority in the air, he concluded, could be maintained only by constant initiative, encouraging inventions leading to new types, and, where necessary, abandoning unsuccessful models even after they have been brought into production" (I. B. Holley 1953, pg. 152). "In the final analysis, doctrine, or the accepted concept of the mission to be performed by the aerial weapon, would inevitably determine the direction of development"(I. B. Holley 1953, pg. 156).

"A somewhat closer study of military history shows that new and more effective weapons have generally been adopted only slowly in spite of their obvious advantage. World War 1 emphasized the necessity for a conscious recognition of the need for both superior weapons and doctrines to ensure maximum exploitation of their full potential. As a corollary to these two requirements, the war pointed up the need for administrative agencies to ensure their fulfillment once they have been recognized as requirements" (I. B. Holley 1953, pg. 175).

Therefore, what are the main issues? Slow adaptation of newer and better weapons despite their obvious advantages. Doctrine is essential to successful system development. A Process is required to develop requirements and systems. The concept must be in place with accompanying doctrine before beginning development. Sufficient analysis must take place to understand all of the variations and their tradeoffs. What is the importance of these issues? The respective lack thereof leads to the development of performance-driven "gold-plated" specifications.

Predecessor to the MPP

The Air Force has tried to address all of the issues above. The MPP is just one of the latest examples of 1. Emphasizing the importance of up-front planning, and 2. Trying to bring formality and

[56] Air Expeditionary Force.

repeatability into the process. Further reasons for its existence as well as its development are discussed below.

Prior to the existence of the Air Force's MPP, the process in place was known as the Vanguard process (Romanelli 1998). There were some major differences between it and the present-day MPP. Chief among these differences was that the Air Force's Acquisition Community determined needs and requirements based upon inputs from the Warfighter Communities. It sought to elicit the right kind of requirements out of users. Because of this approach, Vanguard was known as "requirements-pull". In 1981 it underwent a major change to relate user-defined requirements into an operational capability, and integrating technology planning into the overall process by providing a focus for technology thrusts and transition plans. Vanguard was divided into 10 separate mission areas so that it would align with the mission areas used at Headquarters United States Air Force (HQ USAF) for budgeting purposes (Weishoff 1990). In its original concept, "Vanguard needed to do three things well:

- It should analyze available capabilities and compare them with what is required.
- It should synthesize programs to make up the difference.
- It should provide a means for integrating these programs into a cohesive, meaningful whole, which is tied to the real world of equipment and operations" (Weishoff 1990).

Before the demise of the Vanguard process in 1988, its objective was to help the MAJCOMs better allocate their resources in the POM years by helping them develop a fiscally constrained 20-year roadmap of weapon system concepts and the Science & Technology (S&T) investment program. But the system could not do this automatically. The MAJCOM had to take the Vanguard information and use it to develop the fiscally constrained roadmap. "Many seasoned Air Staff officers thought this was the key to determining the success of the new long-range planning system, actually influencing how the limited resources were allocated among competing requirements during the annual POM battle" (Smith as cited by Weishoff 1990, pg. 76). Unfortunately, constrained financial planning did not occur. It simply could not happen. Two earlier AFIT[57] studies cited by Weishoff "found that the most common difficulties with strategic planning were insufficient time, unpredictable political environment, inadequately defined objectives, inexperienced managers, very difficult cognitive activity, ... {which,}... makes evident the uncertainty of future events, reduces perceived freedom of action, is

[57] Air Force Institute of Technology

computationally tedious, and plans are often made and then ignored" (Corey and Shofner, as referenced by Weishoff 1990, pg. 56). The Vanguard process failed because it fell victim to most of the above factors (Weishoff 1990).

The MPP as it exists today (and as discussed in the previous chapter), is run and executed by the MAJCOM with assistance from the Acquisition Community. This is a key difference between the MPP and the Vanguard Process. Part of this change was to eliminate the stereotypical image of 'pocket-protector 'techies" driving technological-based solutions. Additionally, since this process needed to interface with the Air Force Operational Requirements community (also led and executed by the operational users), it was thought to be a rational improvement to the existing arrangements. Furthermore, it was important that those individuals writing the requirements understood what the concepts presented by the MPP really represented.

Common features between Vanguard and the MPP include their relationship to the PPBS. "A set of fiscally unconstrained alternative weapon systems concepts was then proposed to correct each deficiency. This initial unconstrained investment program usually exceeded the projected available financial resources. ... Since the POM years could not be affected, this created a bow wave effect starting the year after the POM and continuing throughout the planning horizon. The forecast was accomplished by theoretically deleting, cutting, stretching, or slipping individual programs within each mission area" (Weishoff 1990, pg. 42). The MPP captures this unconstrained look with the Mission Area Plan.

Although, the MPP replaced Vanguard largely due to the perceived benefits over the Vanguard process, one element of the Vanguard process was incorporated into the follow-on MPP. This is the use of the Technical Planning Integrated Product Team or TPIPT.

Additionally, legislation changed the relationship between operators and the planning community with help from acquisition professionals. "Goldwater-Nichols played a major role in tipping the scale for the operators over the innovators by empowering the fleet Commanders-in-Chief in the future of requirements generation. This was realized by the creation of the Joint Requirements Oversight Council (JROC) and later the Air Force Requirements Oversight Council (AFROC). Additionally, this legislation created the use of the Chairman's Program Assessment, a formal communication to the

Secretary of Defense from the Joint Chief of Staff where the services were deficient in meeting the requirements of the CINCs. Finally, this legislation created the Integrated Program Priority List (IPPL) for the CINCs. So far, these efforts have been met with mixed results (Smith 1999). In his CNO staff meeting, Admiral Kelso once astutely addressed the question of who sets the technology program requirements. "If you ask the fleet what they want," he said, "they will tell you exactly what's wrong with the equipment you've given them and tell you how to fix it"" (Momiyama 1998).[58] Recent developments is this area include the 'deputization' of the Atlantic Commander (A Naval Admiral) by the Component Commanders to advocate Commander-in-Chief (CINC) priorities to the JROC (CJCS 1999).

Predecessor to the PPBS

Prior to the introduction of the PPBS in 1961, the three military services created their budget submissions independent from each other. For the most part, the services stayed within their traditional roles and missions. However, there were many problems that resulted from this approach. For instance, there were many examples of weapon duplication, little understanding of joint concepts and requirements, and very divergent views on the nation's defense needs and strategy (Salazar 1996).

A Joint DoD and GAO study identified several flaws in the current system. The result was the introduction of a centralized system that sought to overcome those drawbacks (Salazar 1996). The services were to plan weapon system procurements in advance. The new process divided the overall defense budget into ten major force programs containing Program Elements (PEs) that were the basic elements (aircraft, ships, tanks, etc.) of the DoD budget (Salazar 1996). The planning was done within the Five Year Defense Program (FYDP), now called the Future Years Defense Program because it covers six years (execution year and five planning years) (Salazar 1996).

Since the initial introduction of the PPBS, it has been in a constant state of evolution. Most of these changes reflect the different personalities of the Defense Secretary, who exercises control over the PPBS. The Joint Chief of Staff have had varying roles and degrees of influence throughout the evolution of the process, with the latest iteration placing more control in their hands (Salazar 1996).

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[58] December 7, 1998 issue of Aviation Week magazine contains information about the very recent strengthening of the CINCs in determining requirements. The outcome of this action remains to be seen.

Predecessor to Requirements System

The advent of the JROC and other senior decision forums is a relatively recent phenomenon. These have only been present in the existing system since the early 1980s (Salazar 1996). Their formation came as the result of pressures to reform the way the military conducted its acquisition and requirements processes. These pressures were in part due to the 1980 Iranian Hostage rescue debacle and also due to the increasing costs of weapon systems (Salazar 1996).

The advent of a formal Requirements Process emerged only after the introduction of the PPBS. Prior to this time, the informal process in place was to first, identify an existing need, second, establish the requirement, and third, obtain approval for the acquisition from the appropriate acquisition authority (GAO 1974). Since 1961, the acquisition system has been structured and various documents have been used to fulfill the three steps listed above (Lebovic 1996). In all of the services, these documents have had different names but have essentially served the same purposes. Today's Mission Need Statement in the Air Force was a Statement of Need. Today's Operational Requirements Document in the Air Force was a Required Operational Capability (GAO 1974). Furthermore, the process was not as rigid as it is today. For instance, there were no Requirements Documents available for the A-10 aircraft after it had been fielded (in 1974) (GAO 1974). Prior to 1969, Requirements Documents were only generated after a decision to develop a weapon (Lebovic 1996). 1969 marked the introduction of the current Acquisition System of today by Secretary of Defense Packard. Additional changes have been made to the system since that time, like the addition of Milestone 0 in 1977 (Lebovic 1996). Additionally, a GAO report introduced for the first time the notion of "backfill" in 1974. "That is, the documents that currently record the flow of the process for an acquisition were prepared after the fact. We believe this is often the case since decisions are usually made based upon analysis, studies, and the other influences, and then documented" (GAO 1974). The same report also indicated that each system followed its own process and not a formally defined one (GAO 1974). The guidance, regulations, and instructions for the process defined a framework whereby Requirements could be identified, established, and approved. Since then, the notion of "backfilling", and using separate processes for each system's requirements has fallen into disfavor and the current Requirements Generation System expresses these sentiments as a result.

Appendix I - Requirements Documents Necessary to Support Modifications

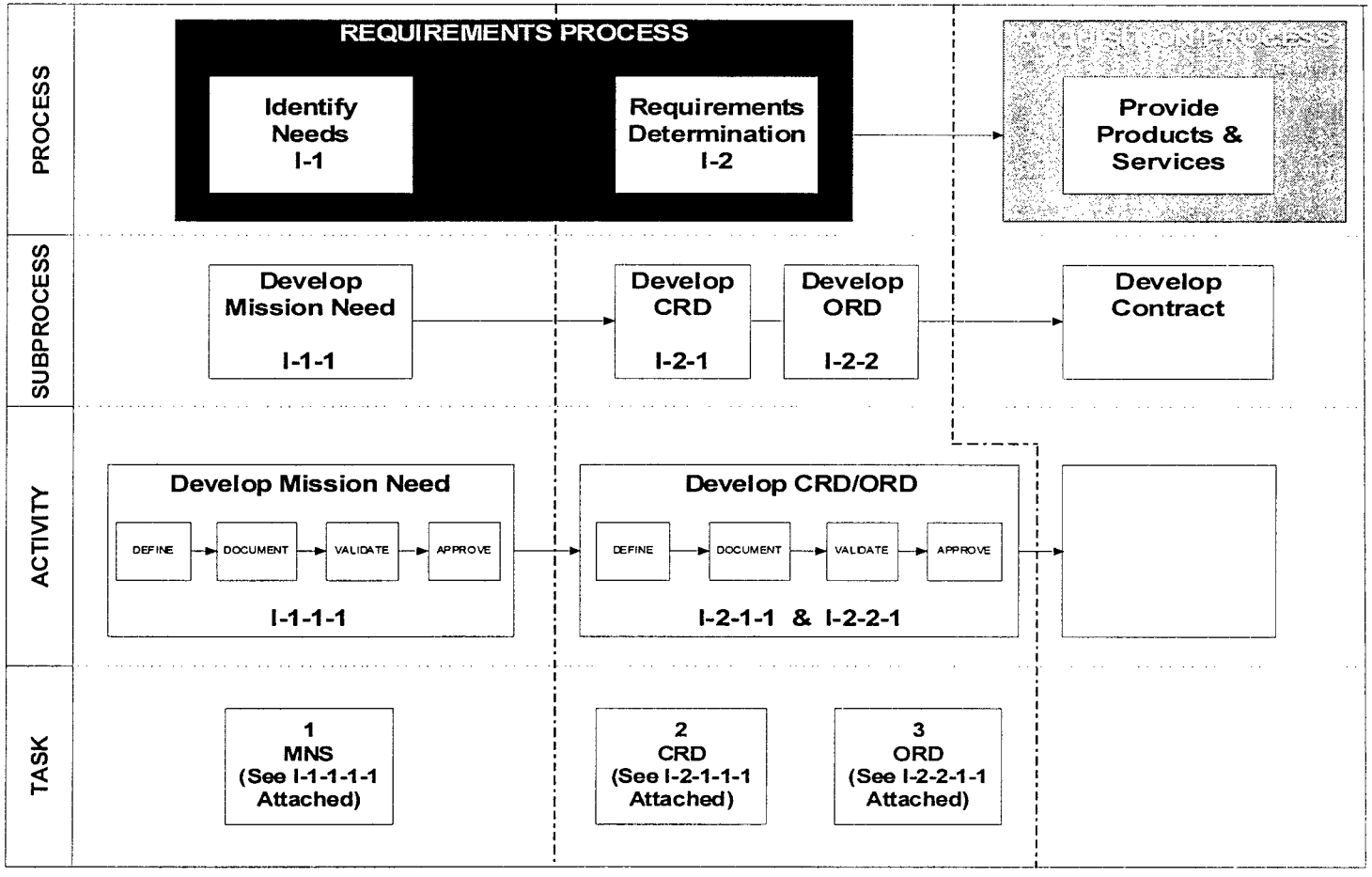
Production Status	Dollar Amount *	Requirements Document	Approval Authority
Pre-MS III	Any Amount	ORD Update or ORD Revision	Appropriate MDA
In-Production (Post-MS III)	Any Amount	ORD Annex or Revision	Appropriate MDA
Out-of-Production	>$65M in procurement OR >$14M in Research, Development, Test & Evaluation (RDT&E)	** MNS to document new deficiency	JROC or CSAF pending potential ACAT designation
Out-of-Production	$10 - $65M in procurement OR $10 - $14M in RDT&E	***AF Form 1067 with Requirements Correlation Matrix (RCM) & transmittal letter	HQ USAF/XOR (Requirements Point of Contact in the Pentagon)
Out-of-Production	<$10M in procurement OR <$10M in RDT&E	AF Form 1067	MAJCOM

* NOTE: All costs in this figure are FY96 Constant year dollars

** NOTE: Modification to an out-of-production system requires validation – DoD 5000.2-R

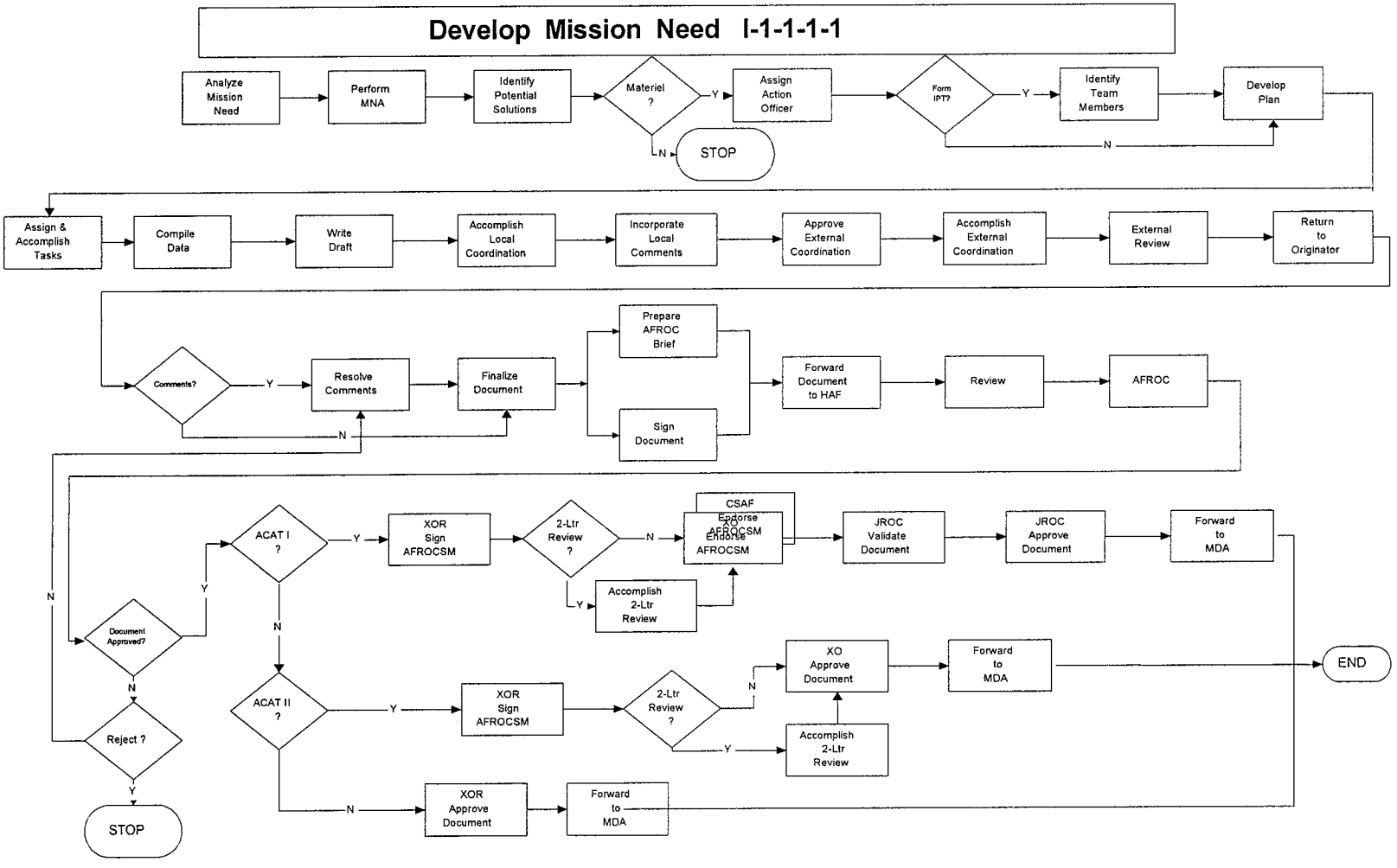
***NOTE: AF Form 1067 is being used in lieu of requirements documentation as required by AFPD10-6. (USAF/DXOR 1999, pg. 25)

Appendix J - Flowcharts on MNS, CRD, and ORD development



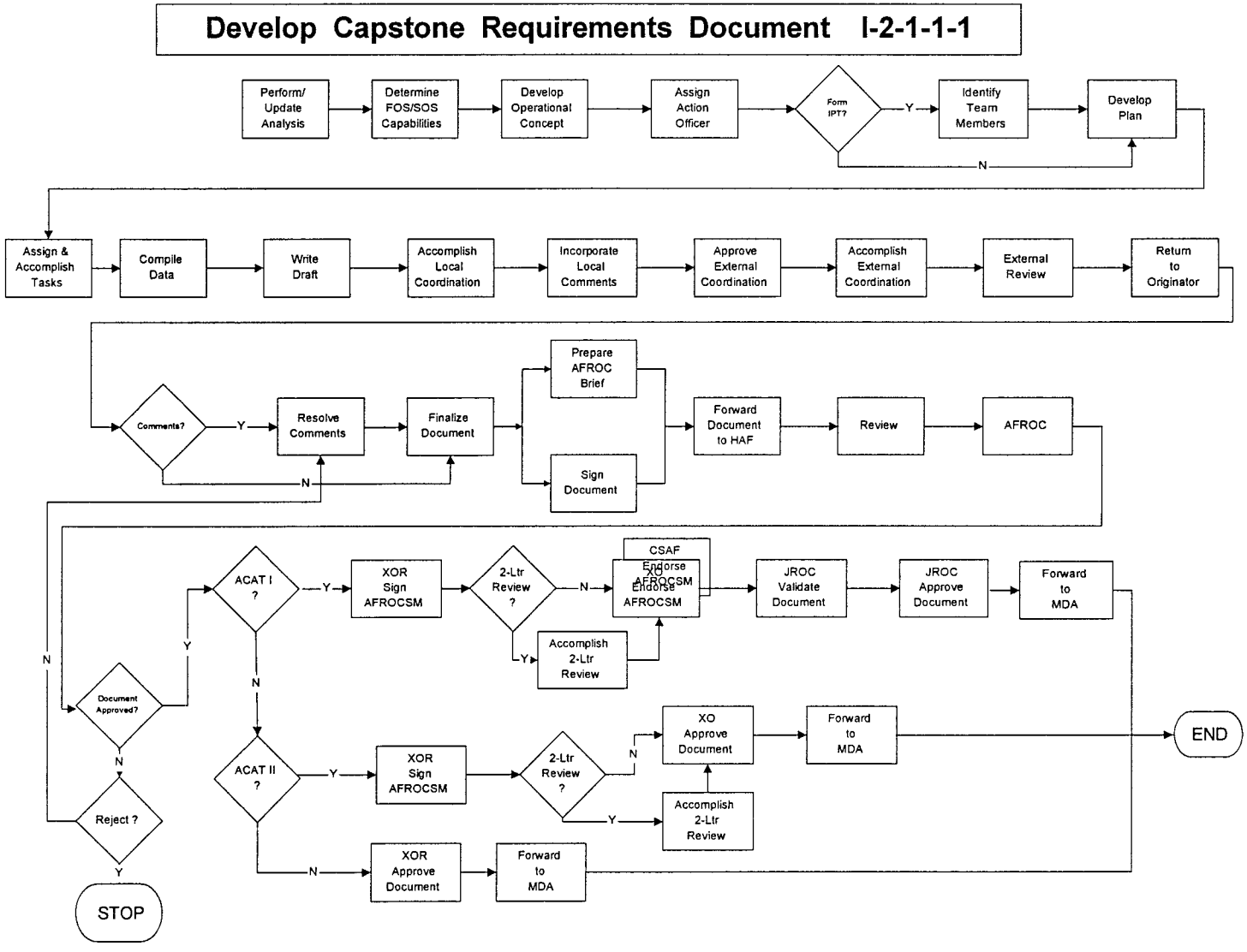
(HAF/XORD 1999)

Figure 82. Overall Requirements Process Flow



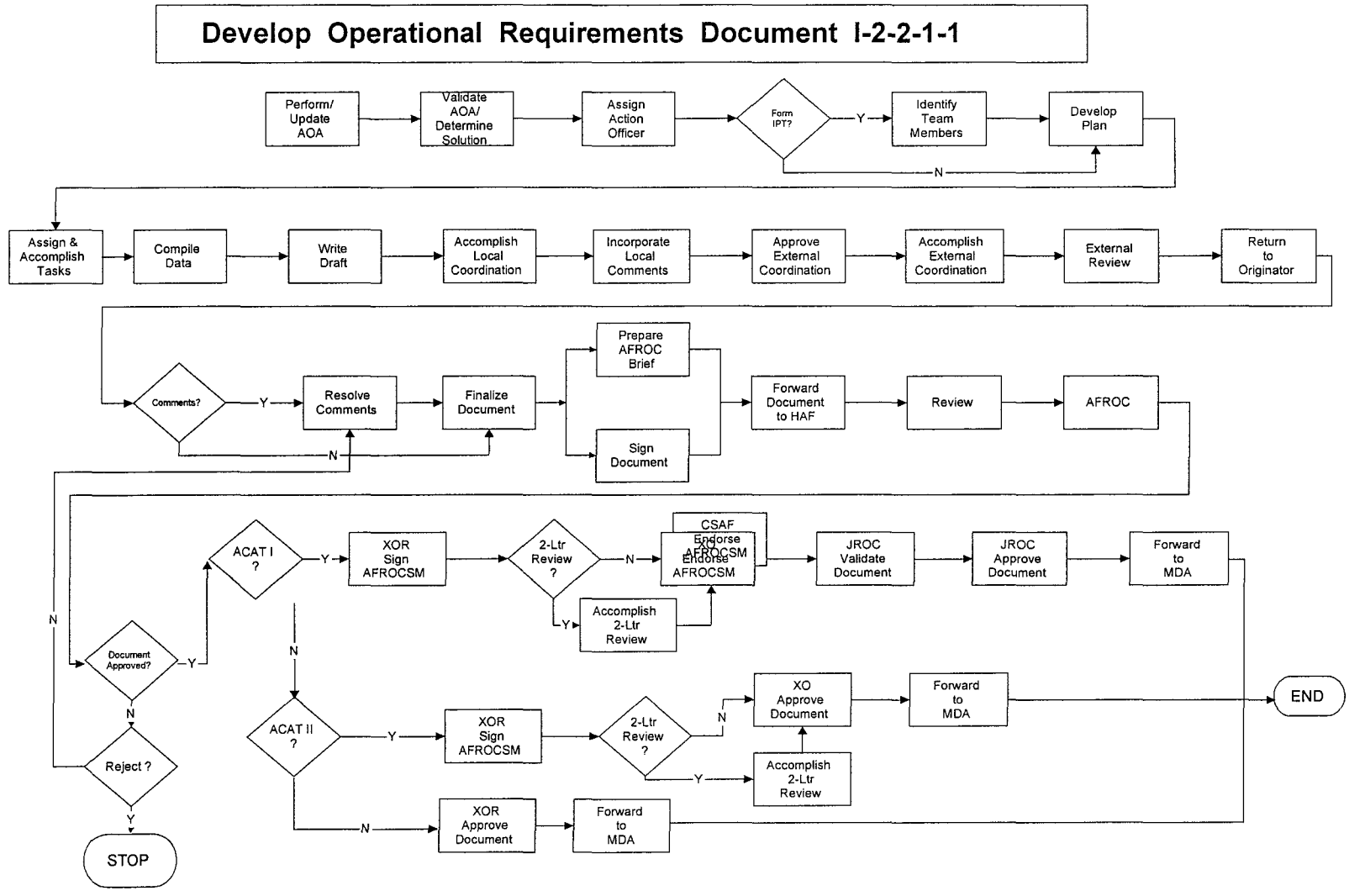
(HAF/ XORD 1999)

Figure 83. Air Force Mission Need Statement Process Flow



(HAF/XORD 1999)

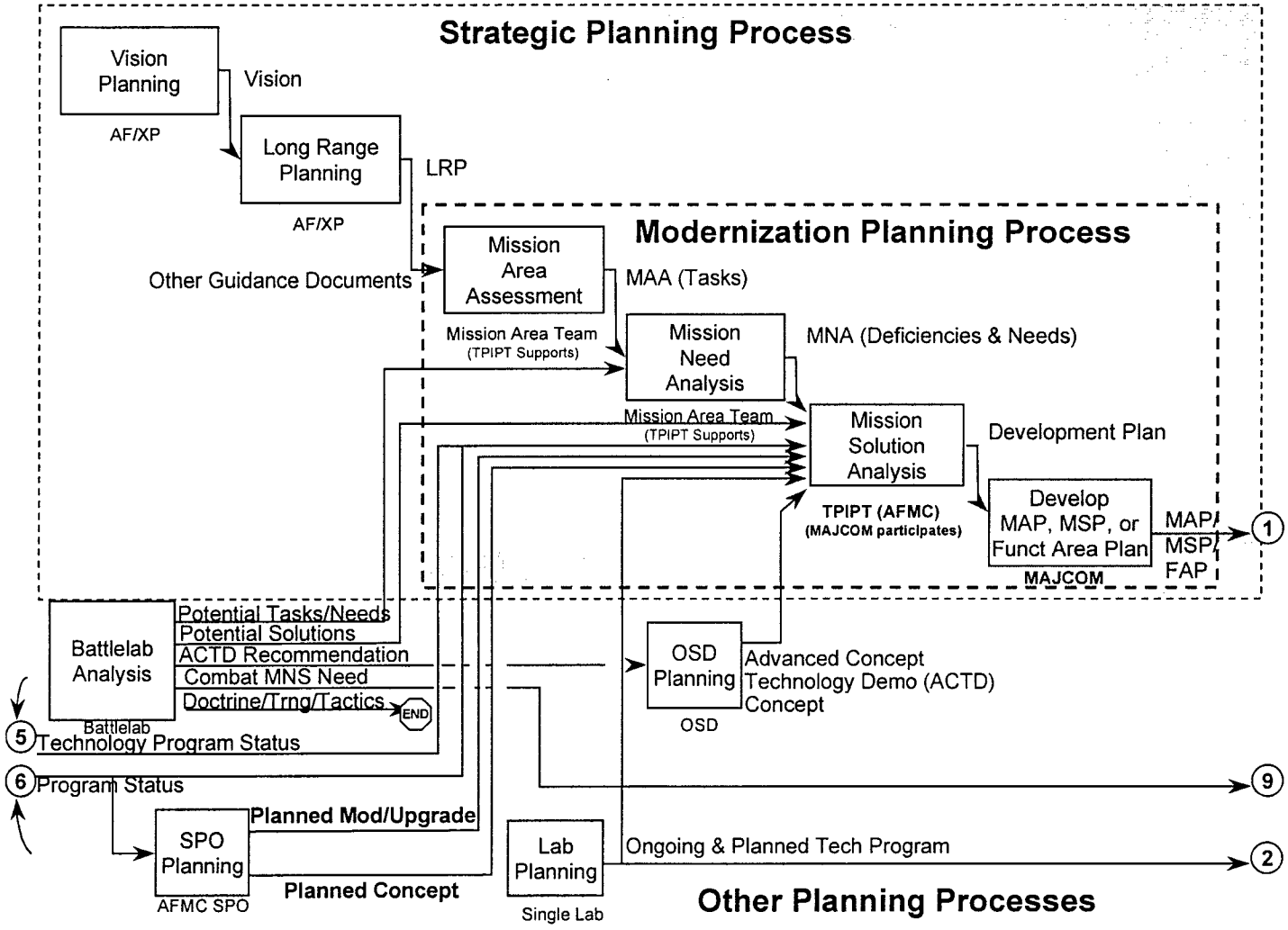
Figure 84. Air Force Capstone Requirements Document Process Flow



(HAF/X ORD 1999)

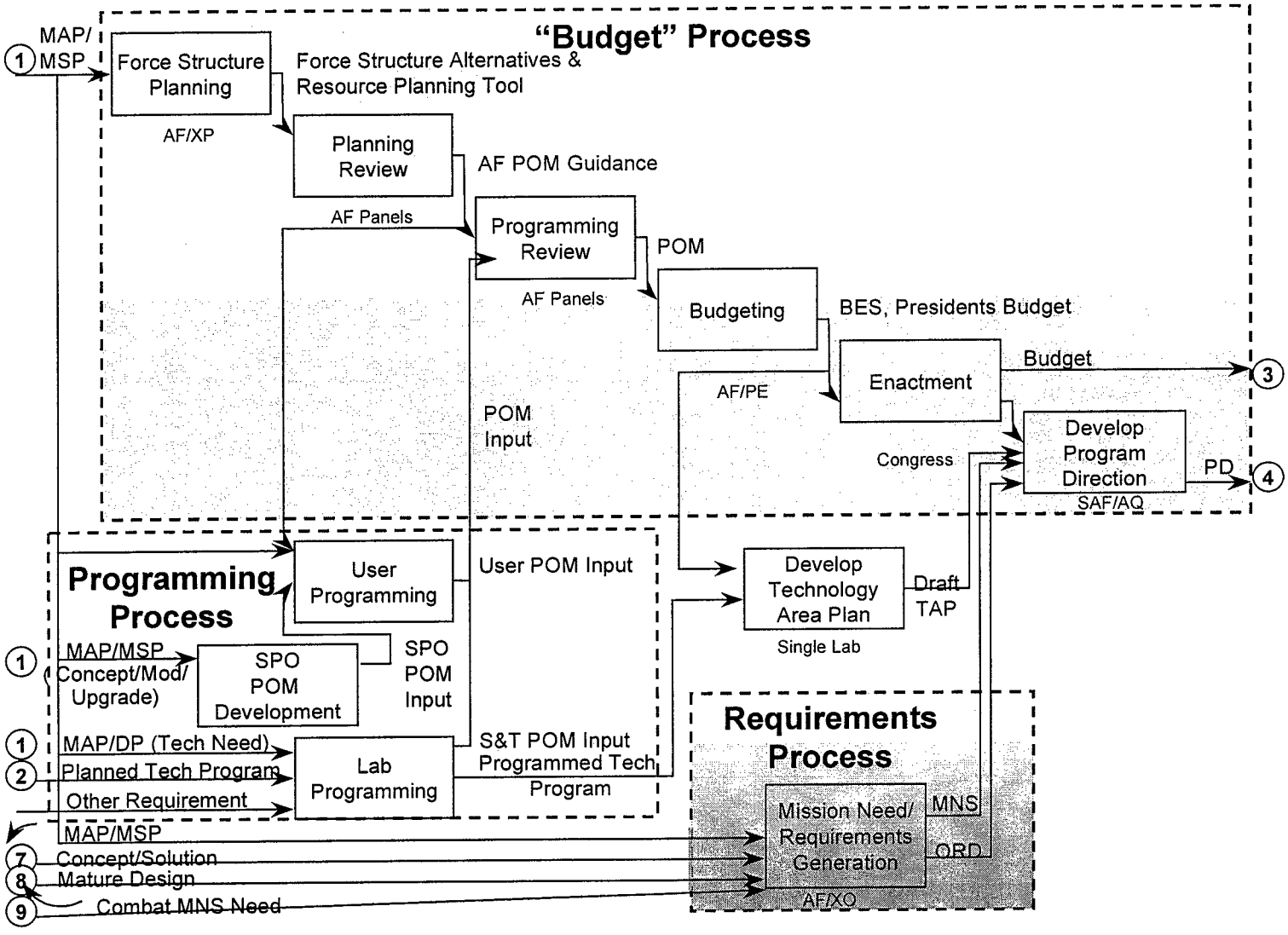
Figure 85. Air Force Operational Requirements Document Process Flow

Appendix K - Overall view of process from AFMC perspective



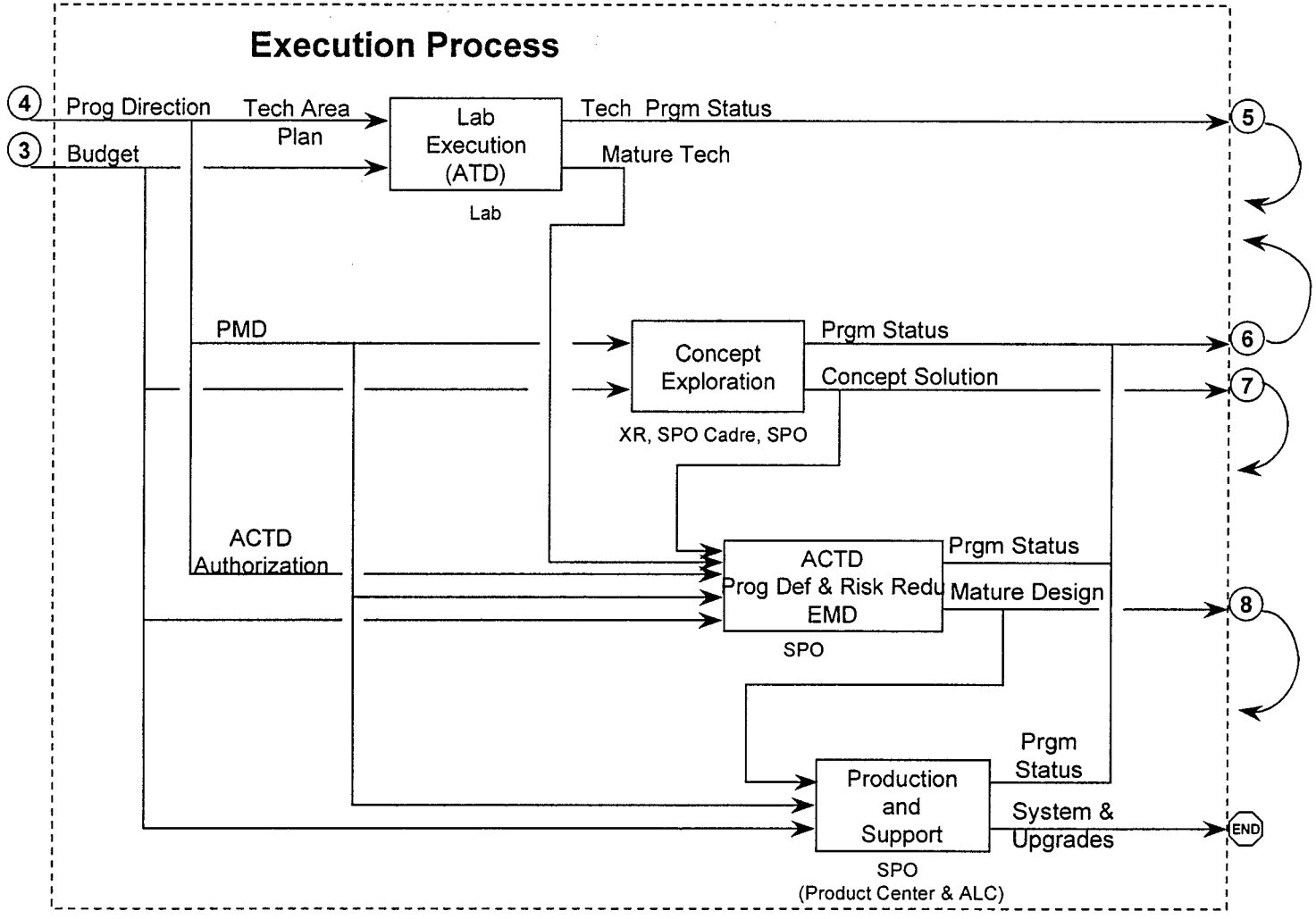
(AFMC 1998)

Figure 86. First slide of AFMC View of Process



(AFMC 1998)

Figure 87. Second Slide of AFMC View of Process



(AFMC 1998)

Figure 88. Third Slide of AFMC View of Process

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